COLUMBIA BASIN FISH & WILDLIFE COMPENSATION PROGRAM

THE CONSERVATION OF HARDWOODS AND ASSOCIATED WILDLIFE IN THE CBFWCP AREA IN SOUTHEASTERN BRITISH COLUMBIA

PREPARED BY

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Prepared for:

THE COLUMBIA BASIN FISH AND WILDLIFE COMPENSATION PROGRAM
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Note on the organization of this report:

The appendices to this report are included on an attached CD-ROM. Maps showing the distribution of hardwoods (1:250,000 scale) in each Forest District are included as ADOBE pdf files. The hardwood data, in ARCINFO format, are available at the CBFWCP office in Nelson. Age class and cover categories by Forest District, Landscape unit and species are provided in Excel spreadsheets.

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EXECUTIVE SUMMARY

Aspen, birch and black cottonwood are an important component of the forest environment in the Columbia Basin, both as pure stands interspersed through the landscape and as individual or small groups of trees within coniferous forests. Our objectives in this project are to:

1. provide an overview of the life strategy attributes of hardwoods and their importance for wildlife;
2. provide an assessment, using forest cover data, of the distribution and age class structure of hardwood stands in the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP) area;
3. assess disturbance history as it relates to the current distribution and abundance of hardwoods;
4. provide an overview of regional land use policies and stand management strategies that affect hardwoods;
5. identify the long term risks faced by hardwoods in the CBFWCP area; and finally,
6. recommend and prioritize conservation and restoration actions that the CBFWCP can undertake with respect to hardwoods.

Hardwood distribution is strongly related to site condition and they are found in most biogeoclimatic zones. They are well adapted to fire and respond well to other disturbance factors such as logging, fluvial process, avalanche activity and construction activities that result in exposed soils. Flooding of riparian areas by dams along the major rivers in the Columbia Basin has been a major factor in the decline of cottonwood stands and related riparian habitats. Browsing by ungulates and livestock has likely had a major impact on aspen and cottonwood recruitment in the Rocky Mountain Trench, Elk Valley and Robson Valley.

Hardwood stands have several attributes important for wildlife. Hardwoods:

- produce exceptionally high biomass in the early years of stand development that is utilized as forage by ungulates and other browsers;
- have a relatively short life span and provide vertical structure, cavity sites, snags, and down wood more quickly than do conifers;
- are more susceptible to heartwood rot at a younger age than conifers and thus provide for cavity creation earlier;
- provide cavity creation situations in live trees more often than do conifers;
- are more susceptible to insect herbivory and thus support larger insect populations than do conifers;
- are more palatable than conifers and thus are used by a range of herbivorous insects and mammalian browsers and finally;
- support a more productive shrub layer and herb layer than generally occurs under conifers, thus increasing the complexity and diversity of bird habitat provided.

As a result, hardwoods are used by a wide range of wildlife species. They provide high forage value to ungulates and other browsers in the early seral stages. They support a diverse songbird fauna in early seral stages, and a different but equally diverse and abundant range of songbirds in mid and later seral stages. There is a high incidence of use by cavity-using species in later seral stages. Birch and aspen are very important to a range of smaller cavity nesters and insectivorous woodpeckers while cottonwoods provide larger cavity sites, created by pileated woodpeckers, that are used by an array of larger birds and small mammals such as fisher. Hardwoods do not provide habitat attributes that do not occur in conifer forests, but they do provide those attributes in greater abundance and at a younger age. As a result, many species show a marked preference for hardwood stands. Where hardwoods occur in riparian areas, very high species diversity and abundance occur. The habitat complexity and richness found in all hardwood stands is amplified by the richness of riparian sites, the larger size and longevity of cottonwood stands and the increase in vertical structure provided by generally taller stands. They also provide habitat for a range of riverine species such as beaver, osprey and cavity nesting ducks. These areas are also critical for songbirds as resting and feeding areas during migration. Hardwoods also play a critical role where they occur as individual trees or as small stands within coniferous stands, primarily by providing cavity nesting sites. We found seven listed species that are dependent to some degree on hardwoods. Most of these occur use hardwoods in riparian areas.

Pure cottonwood stands occur primarily in floodplain riparian areas along the major rivers and tributaries. Aspen stands are found on south-facing slopes and valley bottoms in major valleys in the Rockies and in some parts of the Arrow Forest District (Trail area). Pure stands of birch are very uncommon. All three species are found in mixed wood stands; and as a minor component in the extensive coniferous forests of the area. Pure hardwood stands make up only 1.1% of the total forested area of the study area, however all stands with a hardwood component cover >500,000 ha and 10.8% of the total forested area of the study area. Stands that contain cottonwood are a minor component in all forest districts (<1.9%) except the Robson Valley (2.9%). Aspen is found in 7.4% of stands while birch makes up 4.0% of all stands. The greatest area and percentage of forested area with a hardwood component was in the Arrow Forest District (14.7%).

Age class data for hardwoods show that recent recruitment to hardwood stands is variable between forest districts. The Arrow, Kootenay Lake, Cranbrook, Revelstoke and Robson Valley forest districts show limited recruitment of aspen and birch while the Golden and Invermere areas have substantial areas of young aspen and birch stands. In contrast, cottonwood recruitment is low in the Cranbrook and Invermere forest districts, but is substantial in the other forest districts. Harvesting in conifer stands with a hardwood component has created the disturbance required for hardwood recruitment in many areas, resulting in a substantial hardwood component in many young stands, especially in wet belt areas.

We found that:

- Harvest aimed specifically at hardwoods as a source of lumber or fibre is unlikely to be a major factor in this area in the near future.
- The harvest of conifers will be the major source of disturbance in forests in the Basin in the foreseeable future.
- Hardwoods are well distributed across the forest lands of the Basin at present and constitute a “silviculture problem” in many areas. Silvicultural strategies aimed at optimizing conifer survival may be a factor affecting the survival and recruitment of hardwood species in mixed stands, in the long term.
- Cattle and ungulate grazing is a major determinant of hardwood survival in some portions of the Basin. Elk browsing and fire control in Kootenay and Yoho National Parks have created an age class structure in aspen with essentially no early seral stands (<60 years).

We subjectively assessed a range of risk factors affecting hardwoods against four broad stand types. Based on this assessment, we have come to the following conclusions concerning hardwoods in the Basin:

- The conservation of the remaining cottonwood stands and floodplain riparian areas in the Basin should be considered a priority for the CBFWCP.
- Retaining hardwoods as a minor component (<20%) in the coniferous forests of the study area requires the consideration of researchers and managers throughout the study area. Hardwoods provide an opportunity for maintaining cavity nesting options in those forests that will be managed on a 90 year rotation.
- Mixed wood stands (21-80%) in some areas are subject to pressure for conversion to conifer stands. The CBFWCP should work with the various interests involved to develop a strategy that maintains the critical role of hardwoods in such forests.
- The management of aspen dominated stands, primarily on south-facing slopes should be addressed in order to provide for a mix of ungulate and avian values.

We recommend that the CBFWCP:

- ❑ Sponsor a workshop on hardwood ecology to raise the profile of hardwood issues.
- ❑ Carry out an analysis of age class structure for hardwoods by biogeoclimatic zone and by natural disturbance type.
- ❑ Identify and pursue acquisition and conservation easements in riparian areas along the floodplains of major rivers.
- ❑ Document the loss of mainstem riparian habitats in the Basin.
- ❑ Consider options for maintaining hardwoods in the Trench within Fire-Maintained Ecosystem Restoration plans and activities.
- ❑ In areas outside the trench, assist in the development of a management plan for aspen stands that considers the range of values on such sites.
- ❑ Identify options for manipulating flows below flow-regulating dams to re-establish cottonwood recruitment.

THE CONSERVATION OF HARDWOODS AND ASSOCIATED WILDLIFE IN THE CBFWCP AREA IN SOUTHEASTERN BRITISH COLUMBIA.

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THE CONSERVATION OF HARDWOODS AND ASSOCIATED WILDLIFE IN THE CBFWCP AREA IN SOUTHEASTERN BRITISH COLUMBIA.

1.0 INTRODUCTION

Aspen (*Populus tremuloides*), birch (*Betula papyrifera*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) are a major component of the forest environment in the operating area of the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), both as pure stands interspersed through the landscape and as individual or small groups of trees within coniferous forests. Recent work by Bunnell et al. (1999) and others indicates that hardwood species play a crucial role for wildlife in forest environments in the Pacific Northwest. Some activities of the CBFWCP have altered hardwood stands through slashing and controlled burns to benefit ungulates. Further, there is little information on the impact of fire management, cattle and wildlife browsing, present forest harvest and silvicultural strategies on the long-term health and survival of hardwood species in the study area. Pure hardwood stands (> 80% hardwoods by area) occur throughout the Basin but represent only about 1.1% of the total forest area. However, stands containing hardwoods (in all stands, not just in hardwood leading polygons) cover about 10.8% of the forested land base.

This project provides an overview of the ecological requirements of these hardwood species in the long term and provides guidance to the Compensation Program on restoration efforts that affect hardwood stands. The focus is on black cottonwood, aspen, and paper birch. Sitka alder (*Alnus viridus* ssp. *sinuata*) and mountain alder (*Alnus incana* ssp. *tenuifolia*) were not included in the review. Sitka alder is rare in the Basin and mountain alder is generally treated as a shrub. For simplicity, the three species of interest are referred to in this report as hardwoods. In the literature they are often referred to as hardwood species. Botanically they are most accurately described as broadleaf, broad-leaved, or broadleaf hardwood species.

Our objectives in this project are to:

- provide an overview of the life strategy attributes of hardwoods;
- provide an overview of the importance of hardwood stands for wildlife;
- provide an assessment, using forest cover data, of the distribution and age class structure of hardwood stands in the CBFWCP area;
- assess disturbance history as it relates to the current distribution and abundance of hardwoods;
- provide an overview of regional land use policies and stand management strategies that affect hardwoods;
- identify the long term risks faced by hardwoods in the Basin; and finally,
- recommend and prioritize conservation and restoration actions that the CBFWCP can undertake with respect to hardwoods.

2.0 STUDY AREA

The study area is the operating area of the CBFWCP (Figure 1). This includes the Columbia Basin in Canada, excluding the Flathead, Okanagan, Granby and Kettle River drainages but including a small portion of the upper Fraser River basin, i.e. the Robson Valley. For simplicity, we have described the study area as “the Basin” rather than use the rather lengthy description that is required to describe the study area in detail. The biogeoclimatic units involved are the Ponderosa Pine Zone (Hope et al. 1991a), Interior Douglas-fir Zone (Hope et al. 1991b), Interior Cedar-Hemlock Zone (Ketcheson et al. 1991), Montane Spruce Zone (Hope et al. 1991c), Engelmann Spruce-Subalpine Fir Zone (Coupé et al. 1991) and Sub-Boreal Spruce Zone, found only in the Robson Valley Forest District (Meidinger et al. 1991).

3.0 METHODS

This project is based on a literature review of the ecology of hardwood stands and wildlife use of such stands and an assessment of hardwood distribution and age class structure using BC Forest Service forest cover data. Based on these data sources we then completed a problem analysis looking at risks and options for future actions. We completed electronic searches in federal and provincial government and university libraries in Victoria and Vancouver on the ecology of hardwood species and their use by wildlife. Searches were completed using the following databases for the stated time periods: TREECD, Forestry on CD-ROM (C.A.B. International) 1973-2001/02, AGRICOLA, Agriculture On-Line Access (U.S. National Agriculture Library) 1982-2001/01, and BIOSIS (BioSciences Information Service of Biological Abstracts) 1980-2001/01. As a result of previous reviews of aspen, birch, and cottonwood (Peterson and Peterson 1992, 1995, 1996; Peterson et al. 1996, 1997), the Western Ecological Services Ltd. library contains substantial information sources on silvicultural characteristics and ecological processes associated with hardwoods. We also searched information sources and libraries within the Columbia Basin. We reviewed work, primarily unreported research, by management agencies in the Pacific Northwest portion of the United States and in Alberta. As part of this search, we also reviewed the available literature, using the tools described above, on wildlife use of hardwood species by age class and species, and considered all mammals, birds (breeding and migratory use), amphibians and reptiles. Relevant regional reports and other literature were also reviewed.

The digital forest cover data, provided by the B.C. Ministry of Forests for a complete discussion of MoF’s Forest Resource Inventory program), was queried to generate a series of spatial databases and maps for each forest district within the study area (see http://www.for.gov.bc.ca/resinv/program/about.htm). Results of this query process included, for each forest district, all forested polygons, all polygons with a hardwood component, and a breakdown of the polygons with a hardwood component for four percent coverage classes (1-20%, 21-40%, 41-81% and 81-100%) and nine age classes for each of the three main species, aspen, birch, and cottonwood, within each landscape unit. (For reporting, in some cases we used (1-20%, 21-80% and 81-100% classes). The distribution of hardwood stands, for each species and the three species combined, were then displayed on 1:250,000 maps for each Forest District. The data for the recently created Columbia Forest District is provided for the areas occupied by the previous Revelstoke and Golden Forest Districts since the forest cover data is provided in that format. In addition, age class distributions were developed from the forest cover database for each Landscape Unit. These were then summed to provide age class data graphs for each Forest District. It is important to note that 80% of the age classes by polygon are estimated from height classes on air photos and relatively few polygons are field sampled (C. Hauk, pers. comm.). A detailed description of the computing tools and techniques used is provided in Appendix III.

We present this data with an important proviso. The graphs and spreadsheets show small cohorts of all three hardwoods species in age class 9 (>250 years). These species, and especially aspen and birch, rarely live to this age. This anomaly may be a result of how we analyzed the forest cover data. We included all stands with a hardwood component in the analysis, therefore most of the data in these age class graphs are from mixed stands where hardwoods are a minor component. Where hardwoods are a minor component of the stand, the stand age is based on the age of the leading species, i.e. the most important conifer species in the stand, not the age of the hardwoods (Cal Hauk, pers. comm.). Ages are estimated from tree cores from hardwoods only in stands where a hardwood species was the lead species. It would appear therefore that the older age classes are over-represented in the data presented here. A further problem may apply to the data in younger age classes. Where hardwoods occur in conifer stands in younger age classes, it would seem fair to assume that their ages would be similar since they would both date from the most recent disturbance event. However, in recent work in Wasa area in a separate project (Jamieson et al. 2001), we found a problem with the aging of hardwoods that would suggest that this is not necessarily the case. As part of that project, we attempted to work back from present day age estimates from forest cover data to define stand ages in 1952. Although many young aspen and cottonwood stands were apparent on the air photos in the photos for that year, working back from present age estimates gave us negative numbers. In other words, present age classes for these stands under-estimate the true age of the stand by at least 20 years, or one age class. Most ages in the forest cover database are based on estimates from height class. Aspen in the Wasa area seem to have grown to a certain height and then have stagnated in terms of height growth, resulting in the under-estimate of their ages in the forest cover database.

Hardwood stand management strategies and policies, as expressed in the regional land use plan, Forest Practices Code, biodiversity guidelines and management practise were considered and assessed as to their value to maintaining hardwoods and wildlife species using hardwood stands. We discussed these policies and their implications for hardwoods with a range of resource managers from across the study area.

A risk assessment model used by Harper and Eastman (2000) and others was applied, using a two-stage process to assess the risks faced by particular hardwood stand types. We were uncomfortable with formalizing what are essentially qualitative judgements on the very complex issues involved here. The assessment provided is transparent in that we have provided the arguments used in our risk assessment that a reader may agree or disagree with. However, in our view, the major value of this risk assessment is as a model. This model should be presented to a range of managers and interested parties at some point in the future. That group should be asked to participate in a formal risk assessment process. The summation of assessment by a range of resource professionals would provide a more defensible risk assessment than we were able to do here.

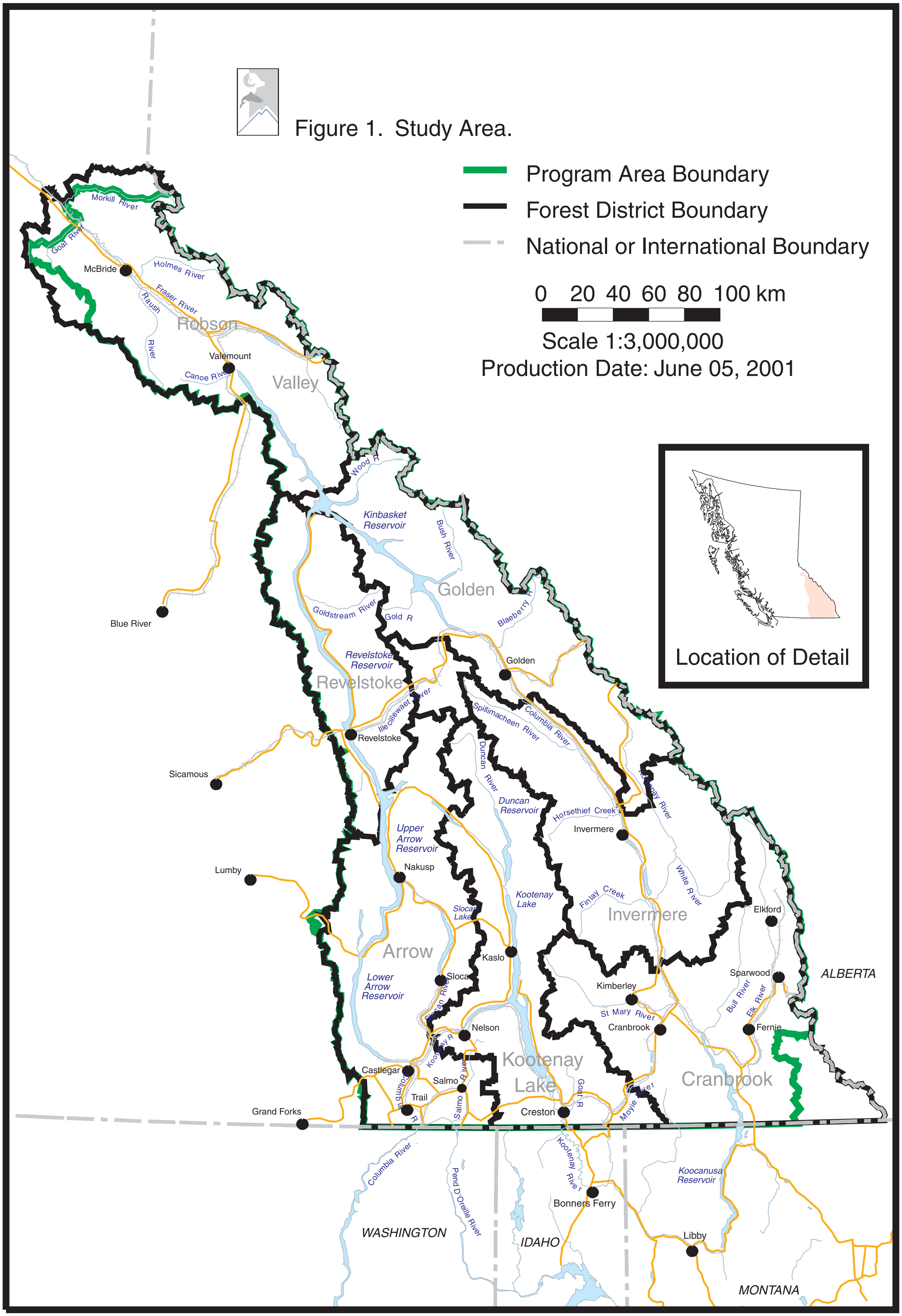


Figure 1. Study Area.

4.0 RESULTS

4.1 THE ECOLOGY OF HARDWOOD SPECIES

Listed below are the ecologically relevant life-strategy attributes of hardwoods in the CBFWCP area. The points highlighted below are given a context and are explained, with references, in Appendix I.

4.1.1 HARDWOOD RECRUITMENT STRATEGIES

Hardwoods have multiple recruitment strategies, as indicated in Table 1.

Aspen can reproduce by seed if there is bare, moist mineral soil available in the short period of seed viability but this species most commonly re-establishes rapidly from suckers that develop from the extensive lateral root system located just below the soil surface. Suckering is triggered when trees are cut or burned and is promoted by the increased soil temperature that results from exposure of soil surface to direct sunlight. Aspen, like birch, also has the ability to produce sprouts from stumps.

Birch reproduces from seed more effectively than the other two species and produce seed in the fall rather than the spring. A characteristic of birch stands is multi-stemmed clumps that are a result of adventitious buds that develop from the root collar following cutting or fire. Birch gradually loses its ability to regenerate vegetatively after about 60 years, in contrast to aspen that can produce root suckers in stands 100 or more years old. However, birch as old as 150 years has the ability to form basal sprouts when the stem is cut, unlike aspen where the ability to produce basal sprouts declines to near zero by age 100. High light intensity and high temperatures stimulate growth of birch sprouts so that sprout growth is faster after clear-cutting than it is after thinning. Birch of sprout origin also grows more rapidly than those of seedling origin.

Cottonwood has the most diverse regeneration adaptations of the three hardwoods. It reproduces very successfully by seed. The best germination of cottonwood seeds occurs on moist soils where there is little competition from other vegetation. Such conditions are provided by point bar formation along rivers and streams. Severe fire, road and skid trail construction and site scarification also provide the exposed soils that are required. Since moist exposed soils occur more frequently in wet climates, recruitment on these kinds of sites occurs more frequently in wetter biogeoclimatic subzones and variants. Cottonwood reproduces vegetatively by sprouting from stumps and from partially buried branch or stem fragments lodged in alluvial parent materials. Cottonwood establishes only infrequently from root suckers and is therefore not as well adapted as aspen for vegetative reproduction after fire. Unlike aspen and birch, cottonwood also has a special form of vegetative reproduction, referred to as cladoptosis, which involves physiological abscission of lateral twigs capable of taking root if they fall on moist soil. Also, unlike aspen and birch, cottonwood takes root readily from stem or root cuttings.

Table 1. Recruitment strategies for hardwood species.

Recruitment strategy	Aspen	Birch	Cottonwood
Seedling establishment	Yes	Yes	Yes
Sprouts from base of stumps	Yes	Yes	Yes
Suckers from roots	Yes	No	Yes
Shoots from broken stems or branches	No	No	Yes
Reproduction from stem or root cutting	No	No	Yes
Cladoptosis*	No	No	Yes

* Lateral twigs, with leaves attached, that can take root when they detach from upper branches.

4.1.2 AGE CLASS STRUCTURE IN HARDWOODS

Some generalizations can be made here about age-class structure in hardwoods. Age-class data based on forest cover data are described in more detail in Section 4.3.5 and in Appendix III. Hardwoods are shade intolerant and thus are not well suited to recruitment of new age cohorts either under their own canopies or under canopies of mixed conifer-hardwood stands. Dense even-aged stands of birch can quickly develop after a disturbance but once established there is little or no further ingress of birch. As a result, many mature birch stands are characterized by a lack of stems in younger age classes. The ability of hardwoods to regenerate under non-shaded conditions means that hardwood age-class structure is strongly influenced by the frequency and intensity of disturbances that remove the over-story. As a result, many individual stands of aspen, birch, or cottonwood are cohorts of a fairly narrow range of ages. However, at the landscape level there is sufficient variation in timing and intensity of disturbances to allow a given landscape unit to contain a wide variety of different aged hardwood stands coinciding with disturbances at different times in the past. Because age-class distributions are strongly controlled by disturbance history that varies regionally and over time, there is no single representative age-class structure for these hardwoods. A consistent feature is a very low representation of age classes over 120 years, especially for aspen and birch.

In general, the longevity of hardwoods is substantially less than that of most conifers. Cottonwoods stands survive into age class 8 (141 to 250 years) but are very rarely found as stands in age class 9 (>250 years) although individuals in that age class may occur. Aspen and birch stands mature much earlier and generally do not survive beyond age class 7 (121 to140 years).

4.1.3 HARDWOOD DISTRIBUTION IN RELATION TO BIOGEOCLIMATIC ZONES AND SOIL MOISTURE/SOIL NUTRIENT CLASSES

Details of hardwood occurrences in the PP, IDF, MS, ICH, SBS and ESSF Zones in the study area are provided in Appendix I. In general, aspen is rated as frequent in the ICH, IDF, MS, SBS and ESSF Zones and is less frequent in the PP Zone. Birch is rated as frequent in the ICH and IDF Zones, and less frequent in the PP, MS, SBS and ESSF Zones. Cottonwood is rated frequent in only the ICH Zone, but it also occurs in the IDF, PP, MS, SBS and ESSF Zones.

Hardwood distribution is more strongly controlled by site conditions than by biogeoclimatic zone. Some key site relations are summarized in Table 2. More detailed information is provided in Appendix I.

Table 2. Site requirements for hardwoods.

Species	Site Requirements
Aspen	Generally found on sites with medium soil moisture and soil nutrient status. Of the three hardwood species, aspen can occur on the broadest range of soil nutrient classes (from very poor to very rich) and in a wide range of moisture classes (xeric to subhydric) except wet sites.
Birch	Of the three hardwood species, birch occurs on the broadest range of moisture classes but is generally absent on sites of very poor nutrient status.
Cottonwood	Cottonwood has the narrowest range of soil moisture classes (submesic to hydric) of the three hardwood species and prefers more nutrient rich sites.

4.1.4 HARDWOOD DISTRIBUTION IN RELATION TO NATURAL DISTURBANCE TYPES

Natural Disturbance Types (NDTs) also play a role in defining the distribution and abundance of hardwoods. Table 3 summarizes the general relations between hardwood occurrence and NDTs within the CBFWCP area. It is based on the subzones and variants in which hardwoods are known to occur or are considered potentially important by the Silviculture Interpretations Working Group (1994) and the association between biogeoclimatic units and NDTs provided by the Biodiversity Guidebook of the Forest Practices Code (BCMOF and BCMOELP 1995).

Table 3. Biogeoclimatic subzones and variants in which hardwoods are significant stand components listed according to NDTs in the CBFWCP area.

Natural disturbance Type	Biogeoclimatic units supporting aspen, birch, and cottonwood in Nelson Forest Region, excluding Boundary Forest District	Biogeoclimatic units supporting aspen, birch, and cottonwood in Robson Valley Forest District
NDT 1	ICHvk1, ICHwk1	ICHwk3
NDT 2	ICHmw1, ICHmw2	ICHmm
NDT 3	ICHdw, ICHmk1, ICHmw3, MSdk	SBSdh
NDT 4	ICHxw*, IDFdm2, PPdh2, IDFun	Nil
NDT 5	Nil	Nil

* The Silviculture Interpretations Working Group (1994) recognized aspen and birch, but not cottonwood, as a significant stand component in the ICHxw Subzone. In all other subzones and variants, all three hardwood species are potentially significant stand components.

As indicated in Table 3, in the CBFWCP area hardwoods can be significant stand components in four of the five recognized NDTs, being absent only in NDT 5 (alpine tundra and subalpine parkland). The greatest numbers of subzones and variants in which hardwoods can be significant stand components are associated with NDT 3 and NDT 4.

4.1.5 THE ROLE OF HARDWOODS IN SERAL SEQUENCES

Hardwoods play a special role in early seral sequences as indicated below.

- Under natural conditions following fire, the typical seral sequence is from herbs or grasses to shrubs and hardwoods and then conifers. However, the seral sequence following forest harvesting is very different. With present silviculture strategies, conifers are planted within a few years of harvest, thus reducing the length of the seral period dominated by grasses, shrubs and hardwood species. This may affect the composition of mixed forests in the long term.
- The development of mixed stands following large-scale disturbances in interior British Columbia usually involves the rapid establishment of many species within 5-10 years, an early dominance of shade intolerant hardwoods and early suppression of shade-intolerant species. This is followed by the establishment of shade tolerant species such as spruce and western red cedar under the stand. In later stages, the creation of small openings due to the mortality of birch or aspen (typically after 40 or more years) results in the release of suppressed shade-tolerant conifers. There is subsequent resorting of species size hierarchies over time as birch or aspen drops out and longer-lived conifers occupy the upper canopy.
- The relative shade tolerances of tree species are a guide to their role and persistence in mixed stands as succession proceeds between disturbances. Tree species from

interior northwest British Columbia are ranked as follows, from most shade tolerant to least shade tolerant: western redcedar > western hemlock = subalpine fir > hybrid spruce > lodgepole pine > aspen > cottonwood = birch. This ranking from northwest British Columbia is considered to be applicable to the CBFWCP area.

4.1.6 THE ROLE OF HARDWOODS IN GAP DYNAMICS

All forests undergo small scale, low intensity disturbances (gap dynamics) if they escape large-scale disturbances. For shade-intolerant species such as aspen, birch, and cottonwood it is commonly assumed that their abundance in mixed stands is closely tied to the last major disturbance that initiated their establishment. However, there is now increasing evidence that where hardwoods are free of disturbance long enough to reach the stage of stem decay and stand breakup (typically 120 years or less) the gradual windthrow or snowload loss of decayed, weakened trees can result in stand openings where these hardwoods previously occupied crown space. This creates the opportunity for early stage succession to be re-initiated, often with reestablishment of a new cohort of hardwood species. What this means for hardwoods in the CBFWCP area is not well documented. However, it does suggest that hardwoods will remain as a minor component in older age forests in protected areas or old growth management areas where forest harvest or fire do not occur.

4.1.7 THE RESPONSE OF HARDWOODS TO DISTURBANCE

The main sources of disturbance that result in a hardwood response are:

- Wildfire
- Disease, insect infestations and snow damage
- Forest harvesting
- Fluvial processes along rivers
- Avalanche activity and soil or rock movement on steep mountain slopes where it results in areas of exposed soils.
- Construction activities that result in exposed soils.

Each of these is described below.

4.1.7.1 Wildfire

Prior to 1950, fire was the predominant source of disturbance in the study area. However, as a result of modern fire management strategies, wildfire has been a minor source of disturbance since that time.

Hardwoods are well adapted to fire, as summarized below.

- **Aspen** is well adapted to fire. Its roots are seldom damaged by fire, heat generated by fire stimulates root sucker production and aspen stands do not support rapidly spreading or intense fires. In fact, pure aspen stands are often considered to be natural fireguards during the growing season because they are less likely to burn than conifer-dominated stands.
- **Birch** is also well adapted to fire. At the landscape level, the dominant disturbances responsible for the current patchy pattern of birch in interior British Columbia are wildfire occurrence and settlement patterns at the turn of the century. Much of this maturing fire-seral birch is nearing its natural ecological rotation age (60-70 years) and is gradually being replaced by late succession conifers.
- **Cottonwood** is not as well adapted to wildfire as are aspen and birch. Cottonwood stands are probably most flammable in autumn and in early spring when ground conditions are dry and the trees are quiescent. Thus fires tend to occur at times when riparian cottonwoods are most capable of sprouting.

4.1.7.2 Disease, Insect Infestations and Snow Damage

Among the many hardwood diseases there are only two processes of regional ecological significance. Stem decay organisms are much more prevalent in cottonwoods than in conifers. This is a major reason why these hardwoods are poorly represented in age classes greater than 120 years. Armillaria and other root diseases play a role in forest gap dynamics and in this context there are differences between hardwoods and conifers. For example, there is evidence that root disease incidence is lower in birch-conifer mixtures than in pure stands of susceptible conifers. The ecological importance of birch in the overall maintenance of forest ecosystem health is recognized, particularly on sites where root diseases are a problem for conifers. In general root disease incidence are higher in pure conifer stands than in conifer-birch mixes. Disease outbreaks rarely overwhelm entire stands but do create patch openings in older hardwood stands. Insect infestations, particularly forest tent caterpillar (*Malacosoma disstria*), have very noticeable impacts in hardwood stands in the boreal forest region. Snow damage is a minor consideration, except in older stands.

4.1.7.3 Forest Harvesting

Hardwoods are an important source of wood fibre in other parts of the province. However, in this area, where there are no oriented strandboard or pulp plants that can use hardwoods, the utilization of hardwoods is low. Fraser and Davis (1996) report that total hardwood scaled in the Nelson Forest Region in 1995 was 13,800 cubic metres, with a further 15,900 cubic metres licensed for whole log export. They identified birch as the hardwood species with the best economic potential in the Nelson Forest District, primarily in the Kootenay Lake and Arrow Forest Districts. Most birch presently being cut is salvaged during harvest in conifer stands. Aspen is not considered economical to utilize, while cottonwood is considered more important to leave for wildlife values than to log.

The harvest of conifers in mixed wood stands will be the main source of disturbance affecting hardwoods in the foreseeable future, especially in the ICH Zone where the largest volumes of hardwoods occur. In most areas where there is a significant hardwood component in the stand, forest harvesting results in significant recruitment of aspen primarily from rootstock, birch from seed and root sprouting, and cottonwood primarily from seed. In some cases, hardwoods can overwhelm conifer establishment and present a silvicultural problem.

4.1.7.4 Fluvial Processes Along Rivers

Most cottonwood recruitment in the drier portions of the CBFWCP area is tied to fluvial processes. Cottonwood very successfully reproduces from seed, but seeds germinate only where there are moist soils, bare ground, and minimal competition. Dynamic seasonal flow patterns, combined with periodic flooding, produce moist, barren substrates that are excellent sites for seedling recruitment (Bradley and Smith 1986, Rood and Mahoney 1990, Rood and Mahoney 1995). The timing of seed dispersal is related to the timing of spring flood events and the wetting of sand and cobble bars. Cottonwood seeds deposit on point bars following the spring flood peak. After germination, roots of the young seedlings keep pace with declining river levels by growing an average of 1.5 cm per day (Mahoney and Rood 1991, 1992, 1998, Selgelquist et al. 1993, Rood et al. 1995). This adaptive advantage allows cottonwood to compete successfully with other vegetation establishing on these sites. The end result is the linear stands of cottonwood seen along most of the rivers in the Basin.

4.1.7.5 Avalanches and Soil or Rock Movement on Steep Slopes

Mud and rockslides on avalanche paths or in steep mountain terrain also provide bare soils that may allow hardwood recruitment. Small aspen and birch stands occur in many such areas in the Basin (Jamieson et al. 1995). Cottonwood stands also occur on such disturbances sites at lower elevations but are less common on these sites than aspen or birch.

4.1.7.6 Construction Activities That Result in Exposed Soils

Hardwood recruitment conditions are provided by road and skid trail construction and by other forms of human initiated disturbance such as dike and highway construction. All of these forms of disturbance create conditions that allow the suckering or seedling establishment of new hardwood stands.

4.1.8 OTHER FACTORS AFFECTING HARDWOODS

Hardwoods are also influenced by two other important factors that are not generally described as disturbances. These are outlined below.

4.1.8.1 Silvicultural Practises

Some reviewers (Bunnell et al. 1997, 1999) have suggested that in the southern parts of its range, aspen is declining as an inadvertent consequence of fire suppression, browsing, and possibly cutting practices. We agree with this assessment, but would add, for this area, post-logging silviculture practises aimed at optimizing conifer production. The major concerns are the immediate planting of conifers after harvest, thus creating a more competitive environment for young hardwoods, and thinning practises that remove hardwoods from mixed stands.

4.1.8.2 Browsing By Cattle and Wild Ungulates

The impacts of cattle and wildlife browsing on aspen stands have been documented in many areas in the United States, in the prairie provinces (Peterson and Peterson 1992), and in British Columbia (Peterson and Peterson 1995). There is less information on the impacts in cottonwood stands (Keigley 1997, Case and Kauffman 1997) although there is an extensive literature from the western United States on the impacts of cattle on riparian areas in general. We found little information on the impacts of browsing on birch. Under high densities or starvation conditions, cattle, horses and ungulates will "bark" aspen and can kill some stems. Browsing by cattle and wild ungulates can suppress and sometimes kill suckers and seedlings of all three hardwood species. In the Elk Valley, for example, an aspen stand that was slashed to provide elk forage responded with thousands of stems per hectare. High use by elk killed almost all of these stems and the site is now tending toward a grassland condition (D. Phelps, pers. comm.). Kay (1997a) has documented this effect across western North America. Such issues are of substantial interest in the Yellowstone area as forest stands there respond to the impacts of the recent fires and a decline in elk numbers due to the re-introduction of wolves. High elk numbers in past decades have reduced or eliminated shrub and hardwood recruitment in many areas in that park. The long-term impacts in riparian areas can also be severe. Case and Kauffman (1997) documented the loss of cottonwood recruitment due to browsing by cattle but notes that cottonwood and willow in riparian areas can respond quickly to the removal of browsing pressure "…*due to the inherent resilience and adaptations to natural disturbance processes displayed by riparian species.*" Cattle and ungulates also tend to remove the shrub layer in both aspen and cottonwood stands with subsequent impacts on songbird use. Livestock grazing has likely had a major impact on aspen and cottonwood recruitment in the Rocky Mountain Trench, Elk Valley, Robson Valley and some other smaller valley bottom areas where cattle are raised. The removal of hardwood regeneration in the Trench has not been documented (T. Ross, G. Berg, pers. comm.), but may be a factor that has altered the abundance of hardwoods in those areas. Impacts are most likely in areas where both cattle and wild ungulate browsing occur. Hardwoods on major winter ranges in the Trench are subject to heavy browsing twice in the year, first in winter and early spring by ungulates, followed by spring or summer browsing by cattle. This has a major impact on grass species (Ross and Wikeem 1993) and may have a similar impact on hardwoods. Cattle numbers are lower in other parts of the Basin and have likely had a much lesser impact. The removal of the shrub layer in cottonwood stands along the Kootenay River by cattle (with native ungulates also playing a role) and the removal of recruitment stands of young cottonwood, is an important issue and is obvious in many areas along rivers in the Trench, the Elk Valley, and in the Creston area.

4.2 WILDLIFE USE OF HARDWOODS

A review of the use wildlife make of hardwoods is included in Appendix II. A synopsis of that information is provided below.

4.2.1 HARDWOOD ECOLOGY AND ECOLOGICAL FUNCTIONS OF VALUE TO WILDLIFE

Certain aspects of hardwood ecology are very important to both vertebrates and invertebrates. These include:

- **Hardwoods produce exceptionally high biomass in the early years of stand development:** Hardwoods have higher rates of photosynthesis per unit of foliage biomass than conifers (Comeau et al. 1996). They apparently take advantage of nitrogen and other nutrients in the soil more effectively than conifers. This early abundance of biomass is available as forage and browse for a wide range of species from insects to large mammals. This attribute also leads to the early creation of vertical structure of value to birds.

- **Hardwoods are more susceptible to insect herbivory and thus support larger insect populations than do conifers:** Bunnell et al. (1999) noted: "*Hardwoods invest less energy in the production of secondary compounds to deflect herbivory (Longhurst et al. 1968). As a result, their leaves host numerous herbivorous insects that benefit canopy feeding birds*." The defensive compounds used by hardwoods are carbon-based compounds that are less effective than the nitrogen based phenolic glycosides, flavanoids and tannins used by conifers (Whitham et al. 1996). As a result, they are used as forage by a wide range of insects, especially lepidopteran (butterflies and moths) and coleopteran (beetles) defoliators. Over 300 species of insects live in aspen stands (Davidson and Prentice 1968, cited in Whitham et al. 1996).

- **The leaves, twigs and bark of hardwoods are more palatable than those of conifers and thus are used by a range of mammalian browsers:** Hardwood leaves, twigs, and bark are higher in carbohydrates and protein than are coniferous needles. They are therefore used as forage by a wide range of mammals, from mice to moose.

- **Leaf, twig and wood litter from hardwoods is greater than from conifers and contains higher levels of many nutrients and thus allows faster cycling of nutrients:** Nitrogen and calcium concentrations in the twigs and leaves of hardwoods are higher than concentrations found in conifers. Along with the lower levels of lignin and terpenes, this allows faster nutrient cycling and improves the value of these plants to soil invertebrates.

- **Aspen and birch have a relatively short lifespan (120 years), compared to most conifers (300+ years):** Hardwoods grow quickly and thus provide vertical structure, cavity sites, snags and downed wood more quickly than do conifers.

- **Hardwoods are more susceptible to fungi infection, heartwood rot and other diseases at a younger age than conifers:** Decay and fungi infection, especially those that lead to heartwood decay, create conditions for the development of natural tree hollows and woodpecker created cavities. Harestad and Keisker (1989) found *Phellinus tremulae* invaded live aspen and created heart rot, while leaving a shell of sapwood, creating excellent conditions for cavities. Winternitz and Cahn (1983) found that all live aspen >40 years were infected with heart rot in their study area. Bunnell et al. (1999) makes the very important point that heart rot occurs in live hardwoods while retaining a sound sapwood shell that allows excavators to create cavities that will last longer than cavities in conifers where heart rot occurs primarily in dead trees. As a result, birch and aspen are very important to a range of smaller cavity nesters and insectivorous woodpeckers while cottonwoods provide cavity sites, created by pileated woodpeckers, that are used by an array of larger birds (wood ducks) and small mammals such as fisher.

- **Hardwoods support a more productive shrub layer and herb layer than generally occurs under conifers:** Hardwoods tend to have well developed shrub layers that constitute a separate and important source of biodiversity within stands. (Note entire section in Bunnell et al. 1999). Many hardwood stands also have a well-developed herb layer. The richness of the shrub and herb layer in these stands increases the diversity and complexity of wildlife use in hardwood stands.

All of these ecological processes within hardwood stands provide attributes of major importance to wildlife. Bunnell et al. (1999) lists cavity sites, downed wood, shrub and hardwoods as critical components of forest environments. All of these attributes occur in hardwood stands. As a result, a wide range of wildlife species use hardwoods. Those that use hardwoods generally are discussed below while those species that use or prefer riparian areas are discussed in the next section. A final section discusses the role of hardwoods where they occur as a minor component in conifer stands.

4.2.2 THE USE OF HARDWOODS IN RIPARIAN AREAS

Bunnell et al. (1999) pointed out that 48 to 55% of terrestrial vertebrate species are restricted to or prefer riparian habitats, across the range of British Columbia biogeoclimatic zones. Several studies have documented that riparian areas occupied by conifers have higher biodiversity and species abundance than adjacent upland areas. Where hardwoods occur in the riparian zone, very high biodiversity and species abundance both occur (Bruce et al. 1985, Achuff et al. 1984, Bunnell 2000.). This is the result of several factors that include:

- The factors described above that contribute to the ecological value of hardwood stands generally are amplified by the richness of riparian sites, resulting in better conditions for cavity creation, greater insect numbers, etc. This is a result of increased basic productivity due to year round soil moisture, generally good soils and usually, lower elevations and longer growing seasons.
- The presence of aquatic and terrestrial habitats in close proximity provides many niche opportunities not found in upland areas.
- The dynamic disturbance factors that occur in riparian habitats, especially on the floodplains of larger rivers, create a range of seral stages and a range of other habitat

types (sandbars, mudbars, wet meadows) that contribute to the overall value of such sites to wildlife.

- The larger size and longevity of hardwoods (generally cottonwood stands) result in larger bole size and thus provide for larger cavity sites. The increase in vertical structure provided by generally taller stands increase their value to many species of birds.

In addition to these geomorphic, soil, climate and nutrient factors, there are four important biological factors that operate in riparian areas. These are the presence of fish in adjacent aquatic habitats, high insect numbers due to the presence of both aquatic and terrestrial habitats and the activities of beaver and pileated woodpecker. All of these factors play a role in increasing both habitat complexity and quality for other species. The presence of fish as a food source and the general dynamic and highly productive nature of such systems means that, although they may use upland areas, they tend to spend much of their life in riparian areas. These include osprey, great blue heron, belted kingfisher, fish feeding ducks and bald eagle). Kokanee spawning areas are especially rich, although other salmonids and nongame fish are also an important food source. Very high insect densities are found in floodplain complexes due to a combination of rich and complex terrestrial habitats, including hardwoods which support higher insect densities than do conifers, aquatic habitats in both the main river and in side channels), wetlands, and seasonal ponding as a result of spring floods, often with high mosquito larval production. The total diversity and density of the terrestrial and aquatic insects found in these areas are substantially higher than in adjacent upland areas and are critical to many birds, amphibians and small mammals (Naiman et al. 1992, Ward et al.1998). Beaver also play a pivotal role in riparian processes, both in smaller streams where their dams alter hydrologic, sediment and nutrient regimes in major ways (Naiman et al. 1988), and in larger streams where they live in bank burrows and alter vegetation through their feeding activities. The larger tree bole size found in hardwoods in riparian areas results in high use by pileated woodpeckers which in turn creates nesting sites for a very wide range of species due to the size of the cavity provided. Of the species that use these cavities, several are riparian or wetland obligates which do not use such cavities in upland areas. Smaller woodpeckers also use riparian areas preferentially since feeding areas and potential cavity trees both occur in abundance, especially where hardwoods occur. Cavities created by smaller excavators provide cavities for small nesting birds such as swallows, bluebirds, chickadees, house wren, rough-winged swallow, starling and swifts.

4.2.3 THE USE OF HARDWOODS BY MAMMALS

As indicated in Table 4, many mammals use birch, cottonwood and aspen. The sapling stage of hardwoods is used as a source of browse by a range of mammals, from rodents to large ungulates. Aspen saplings are the most attractive to ungulates, followed by cottonwood, while birch is less attractive. They also use such areas as summer thermal cover and older stands are “barked’ to provide winter forage, generally under severe deep snow conditions. Older stands are also used by several cavity-nesting mammals such as fisher, marten, and flying squirrel. Vonhof and Gwilliam (2000) found two large bats (the big brown bat and silver-haired bat), that showed a marked preference for older age aspen as roosting sites.

Riparian hardwood stands support one mammal that does not occur in upland hardwood stands, i.e. beaver. However, riparian sites support higher densities of some species due to the larger bole size found there and thus better options for the creation of larger cavity sites. Fisher, for example, uses riparian areas preferentially for natal denning sites.

Table 4. The use of aspen, birch and cottonwood stands by mammals.

Wildlife Species	Age Class 1+2 1-40 years	Age Class 3-4* 41-80 years	Age Class 5-8** 81-250 years
Grizzly Bear***	[feeding on under story plants]	[summer thermal cover]	[summer thermal cover]
Black Bear	[feeding on under story plants]	[feeding on spring aspen buds]	[summer thermal cover]
Moose	[feeding on young hardwoods]	[summer thermal cover]	[summer thermal cover]
Elk	[feeding on young hardwoods]	[summer thermal cover]	[summer thermal cover]
W.T. Deer	[feeding on young hardwoods]	[summer thermal cover]	[summer thermal cover]
Mule Deer	[feeding on young hardwoods]	[summer thermal cover]	[summer thermal cover]
Fisher			[use cavities as natal nests]
Marten			[use cavities as natal nests]
Beaver	[feeding on young hardwoods]	[feeding, dam and home construction]	[feeding, dam and home construction]
Porcupine	[feeding on hardwood bark]	[feeding on bark]	[feeding on hardwood bark]
Big Brown Bat		[use cavities as roosting sites]	[use cavities as roosting sites]
Silver-haired Bat		[use cavities as roosting sites]	[use cavities as roosting sites]
Flying Squirrel		[use cavities as roosting sites]	[use cavities as roosting sites]
Red Squirrel		[use cavities as roosting sites]	[use cavities as roosting sites]
Rodents	[feeding on young hardwoods]		
Rabbits/Hares	[feeding on young hardwoods]		

* These are meant only as a general guide to use by age class. Bole size, the age of onset of heartrot and thus the value of the stem to cavity nesters will vary widely by site.
** Hardwoods do not generally live into age class 9.
*** Red and blue listed species are indicated in **bold.**
**** Riparian obligate species are indicated in *italics.*

4.2.3 THE USE OF HARDWOODS BY BIRDS

Several authors have looked at the use of hardwoods by birds. Enns to al. 1993 provides a provincial review of wildlife use of hardwoods, for example. Hardwoods are used preferentially by several grouse, hawk, owl and woodpecker species and by a range of songbirds. Except for grouse, which feed on the buds, the primary attraction is the presence of cavities and high insect numbers. Songbird use is much more complex and we have attempted to show their use by feeding and nesting guilds Table 5a). There is little data on songbird use across seral stages for birch or cottonwood stands in B.C. There are however three good studies of bird use of different seral stages in aspen stands in the Smithers area (Pojar 1995) and in Alberta (Westworth and Telfer 1993, Schieck and Nietfield 1995). Ferguson (1998) looked at bird use in aspen stands in the Golden area. This work indicates that younger age class stands (0-40 years) are used by grouse and by some generalist and open habitat birds (shorebirds, sparrows, some warblers, robin, junco) while pole age stands (21-60 years) are used by some of these species plus a range of shrub nesting songbirds. Older stands see increased songbird use for nesting and feeding, with canopy gleaners and nesters making up a larger proportion of the total bird population. Shrub nesters continue to be present in stands with a strong shrub understory. Mature stands continue to be used by songbirds for nesting (foliage gleaning, and bark gleaning, wood drilling, aerial foraging and nectar foraging guilds are added) and there is a major increase in use by a range of cavity nesters as heart rot enters trees in the stand. Old stands (>80 years) see more extensive use by cavity nesters. At this stage conifers generally enter the stand as an understory, adding further habitat complexity and species.

In all of these studies, the levels of species diversity and the abundance of birds are similar across the life cycle of aspen, i.e. one life stage does not provide substantially greater diversity or abundance than other life stages. However, the species using each stage are very different, as described above. Pojar 1995 notes that stand age is only one component of a mix of factors that contribute to bird community diversity and density. The presence in the stand of a herb and shrub layer, of openings, water areas, snags, cavities, canopy heterogeneity (Schieck and Nietfield 1995) and conifers all contribute to species diversity and abundance.

Table 5. The use of aspen, birch and cottonwood stands by birds.

Wildlife Species	Age Class 1+2 0-40 years	Age Class 3-4* 41-80 years	Age Class 5-8** 81-250 years
Ruffed Grouse	[feeding]	[feeding and cover]	[feeding and cover]
Sharp-tailedGrouse* **		[winter cover and feeding]	[winter cover and feeding]
Golden Eagle			[use for perching during migration]
American Kestrel			[use cavities as natal nests]
Cooper's Hawk			[nests preferentially in hardwoods]
Northern Goshawk			[nests preferentially in hardwoods]
W. Screech Owl			[feeding and cavity nesting]
N. Saw-whet Owl			[feeding and cavity nesting]
N. Hawk Owl			[feeding and cavity nesting]
Great Horned Owl			[feeding and nesting]
Great Grey Owl			[feeding and nesting]
Boreal owl			[use hardwoods in conifer stands]
Pygmy Owl			[use hardwoods in conifer stands]
Barred Owl			[use hardwoods in conifer stands]
Pileated Woodpecker			[feeding and cavity nesting]
Red-Naped Sapsucker		[feeding and cavity nesting]	[feeding and cavity nesting]
Downy woodpecker		[feeding and cavity nesting]	[feeding and cavity nesting]
Hairy Woodpecker		[feeding and cavity nesting]	[feeding and cavity nesting]
Northern flicker		[feeding and cavity nesting]	[feeding and cavity nesting]
Lewis's woodpecker			[cavity nesting near grasslands]
*Bald Eagle*****			canopy nesting near water
Osprey			canopy nesting near water
Great Blue Heron			[canopynesting near water]
Belted Kingfisher		[perching]	[perching]
Common Merganser			[cavity nesting close to water]
Hooded Merganser			[cavity nesting close to water]
Bufflehead			[cavity nesting close to water]
Wood Duck			[cavity nesting close to water]
Barrow's Goldeneye			[cavity nesting close to water]
Common Goldeneye			[cavity nesting close to water]

Figure 5. (continued)

Wildlife Species	**Age Class 1+2 0-40 years**	**Age Class 3-4* 41-80 years**	**Age Class 5-8** 81-250 years**
Songbird Guilds*****			
Ground nesters	[nesting]		
Shrub nesters	[nesting]		
Tall shrub nesters	[nesting in young stands]	[nesting in understory]	
Tree canopy nesters		[nesting]	[nesting]
Cavity nesters			[nesting]
Ground gleaners	[feeding]		
Foliage gleaners		[feeding]	[feeding]
Bark gleaning		[feeding]	[feeding]
Wood drilling		[feeding]	[feeding]
Aerial foraging		[feeding]	[feeding]

* These are meant only as a general guide to use by age class. Bole size, the age of onset of heartrot and thus the value of the stem to cavity nesters will vary widely by site.
** Hardwoods do not generally live into age class 9.
*** Red and blue listed species are indicated in **bold.**
**** Riparian obligate species are indicated in *italics.*
***** Based on Pojar 1995, Westworth and Telfer 1993 and Schieck and Nietfield 1995

We found little evidence of “obligate species” for hardwoods. It appears, based on the studies we looked at, that it is stand attributes provided by hardwoods, (insect abundance, shrub layers, etc.) rather than hardwoods per se, that make these stands of such importance. Hardwoods do not provide habitat elements that do not occur in conifer forests, but they do provide these habitat elements in greater abundance and at a younger age. As a result, most species show a marked preference for hardwood stands rather than demonstrating an explicit requirement for hardwoods in order to survive. Pojar (1995) identified a few species that appeared to prefer aspen stands (Least Flycatcher, Red-eyed Vireo, Western Wood Pewee in her study and Hermit Thrush, Warbling Vireo and Swainson’s Thrush in other studies). However, the species involved seem to vary between studies and study areas. Several warblers and other songbirds, for example, are identified as possible hardwood obligates in studies in northeast B.C., but these are boreal species that do not occur or are very uncommon in the CBFWCP area (See Appendix II).

It total, it is apparent that a very wide range of bird species use hardwoods and especially cavities in hardwoods, preferentially, or for a portion of their life cycle. They play an even more important role in two special cases, i.e., in riparian areas and as a component in conifer stands.

4.2.4 THE USE OF RIPARIAN HARDWOOD STANDS BY BIRDS

Hardwood stands, primarily cottonwood stands in riparian areas provide important habitat for songbirds (Martinsen and Whitham 1994, Whitham et al. 1996). One author suggests that western riparian habitats support the highest non-colonial avian breeding densities in North America (Johnson et al. 1977). Leung and Simpson (1994) looked at bird communities in the Columbia valley. They found greater diversity and density in riparian cottonwood stands than in upland IDF, MS and ESSF stands, but there was not a large difference between riparian and upland sites in the ICH. However, Achuff et al. (1984), working in Glacier and Revelstoke National Parks, found higher densities of songbirds in hardwood stands in the ICH than in ICH coniferous forest and much higher densities in a “floodplain complex“ of cedar, spruce and cottonwood.

Hardwood stands in riparian areas support a bird fauna that is substantially more diverse than that found in upland hardwood sites.This includes cavity nesting waterfowl and several species that depend on fish as a food source. In addition, recent research suggests that riparian areas are critical for songbirds as resting and feeding areas during migration. Krueper (1993) found that over 60 percent of neotropical migrants used riparian areas in the western states as stopover areas during migration or for breeding habitat. Stevens et al. (1977) reported riparian plots that contained over ten times as many migrant passerine species as adjacent non-riparian plots. Petit (2000) found that a multitude of factors affect songbird choice of stop-over locations (similarity to breeding and wintering habitat, geographic location, presence of corridors between sites, insect and seed/berry food sources). This role is especially important in the American portion of the Columbia Basin and other parts of the American west where riparian cottonwoods are often the only large tree stands available to migrating birds in landscapes dominated by semi-desert vegetation types. The importance of riparian areas for songbirds may be less pronounced in this area where adjacent upland areas are forested and provide better bird habitat than do the semi-desert areas found further south. However, it is likely that riparian areas are used preferentially by migratory songbirds due to the habitat richness and habitat diversity found in such areas. The presence of high insect numbers, late season berries and seeds and the longer growing season all contribute to this role.

4.2.5 THE USE OF RIPARIAN HARDWOOD STANDS BY FISH, AMPHIBIANS AND REPTILES

Riparian areas and especially hardwood stands also provide increased amphibian and reptile richness (McComb et al. 1993, Gomez and Anthony 1996). These areas also provide important values for fish in adjacent aquatic habitats by modifying water temperature and providing a source of terrestrial invertebrates that are used by fish. When cottonwoods fall into rivers and streams they also provide fish cover and when washed downstream, they often form log jams which provide important pool habitat and alter river mechanics in subtle but important ways (Braatne et al. 2001).

4.2.6 THE VALUE OF HARDWOODS AS A COMPONENT IN CONIFEROUS STANDS

Hardwoods occur in the Basin within coniferous stands, as individual trees, as clumps or small stands distributed through coniferous stands, or as a significant component in mixed wood stands. There is evidence that hardwoods are of special importance to maintaining wildlife populations in such stands and that it is the mix of hardwoods and conifers that is critical. Hardwoods, when they occur as large bole trees, provide opportunities for cavity development and cavities that are used by fisher, marten, and flying squirrels, primarily as natal dens. Steeger et al. (1996) found that 75% of observations of foraging by woodpeckers in B.C. were in conifers while most nests were found in hardwoods. Martin et al. (1997), looking at bird communities in aspen stands in the Chilcotin, found that 96% of 1100 active cavity nests were in aspen, although aspen made up only 15% of the trees available. They also noted however, that 75% of the foraging time of flickers and sapsuckers was in conifers. In a recent study of songbirds in the MSdk and ESSFdk east of Invermere (Stuart-Smith 2001), hardwood trees were found to be one of the key predictors of songbird species richness and abundance in stands less than 45 years of age. This was even after covariants such as stand age, elevation and disturbance history had been taken into account. At an individual species level, broadleaf trees positively influenced the abundance of many species, including Black-capped and Mountain Chickadees, Dusky Flycatcher, Warbling Vireo, and Red-naped Sapsucker. These species were all found to nest in aspen trees, either in cavities (chickadees and sapsucker) or in hanging cup nests from the lower branches of smaller trees (flycatcher and vireo).

Bunnell (2000) provided a review of a range of studies that document the importance of the hardwood component in conifer forests. Bunnell et al. (1999), Bunnell (2000) and others have been drawn to the conclusion that **a hardwood component within conifer stands is of extraordinary importance in contributing to diversity within conifer-dominated stands.** We would add that, for those portions of the landscape that will be managed on a 90 year rotation, that hardwoods will likely provide a major source of cavity nesting options within these forests. Present snags are being removed with logging due to Worker’s Compensation regulations. The only other source of potential snags and cavity sites will be in stumps and where trees have been cut at 10-12 feet above ground to provide surrogate snags.

4.2.7 RED AND BLUE LISTED SPECIES THAT USE HARDWOODS

We consulted the B.C. Conservation Data Centre lists and found the following:

Plant communities: Two hardwood dominated plant communities are red-listed for the Invermere and Cranbrook Forest Districts. These are:

- Black cottonwood/red-osier dogwood/Nootka rose in the PPdh2
- Ponderosa pine/trembling aspen/rose/Solomon’s seal in the PPdh2

No hardwood-dominated communities are listed for any of the other forest districts.

Vascular Plants: Listed plant species are provided only as long lists for each Forest District with no analysis by forest type. Interpreting which plants occur in hardwood-dominated stands is beyond the scope of this work.

Mammals: There are no red-listed mammals that use hardwood stands. Grizzly bears use riparian areas but are not specifically keyed to hardwood stands (B. McLellan, pers. comm.). **Fisher** is blue-listed for the Kootenay Lake Forest District. They are dependent on cavities for natal dens. Cavities are more common in hardwoods and therefore play a role for this species (Banci 1989, Fontana et al. 1999, Forest Practices Code 1997). Long-eared myotis is blue listed for the Robson Forest District, however Vonhof and Gwilliam (2000) found that long-eared myotis used conifers for roosting rather than hardwoods. The Townsends’ big-eared bat is listed for the Arrow Forest District. This species uses low elevations and riparian areas but there are no data that suggest that they are explicitly dependent on hardwoods (L. Ingham, pers. comm.).

Birds: The **Western Screech Owl** is the only red-listed species (Kootenay Lake, Cranbrook, Invermere, Columbia Forest Districts) in the study area. This is a non-migratory owl that is common on the coast but rare to uncommon in the central interior and very rare in the Kootenays. It nests in hardwood and coniferous riparian habitats at lower elevations and in urban areas below 540 m. It is a cavity nester although most nests found are in nest boxes (Campbell et al.1990). Enns et al. (1993) indicated that they need trees >30 cm dbh. This suggests that older age hardwood stands are important for this species.

Several blue-listed species show a preference for hardwoods or use hardwoods for part of their life cycle (Table 6). All of these depend on older age stands of hardwoods. The following species are listed for the Cranbrook, Invermere, Columbia and Kootenay Lake Forest Districts and show some association with hardwood stands.

- **Sharp-tailed Grouse:** Aspen stands are important during winter storm events, as cover and as a source of food (buds).
- **Lewis' Woodpecker:** This woodpecker uses cottonwood stands adjacent to grasslands for nesting in some areas. They also use large-bole conifers and snags.
- **Great Blue Heron:** Herons use older age cottonwood stands for roosting.

No songbirds that use hardwoods are listed for the study area; however, there are some songbirds that are listed for the northeast portion of the province that use hardwood stands, mainly boreal or prairie species whose ranges extend into the northeast corner of the province. One vireo and five species of warblers are listed for the Fort St. John Forest District. Some of these occur in the Robson Valley and Golden areas but, based on studies to date, they are rare or uncommon (see Appendix II.).

Fish: Cutthroat trout and **bull trout** are blue listed for some forest districts. Streamside cottonwood stands modulate stream temperature by shading of smaller streams, are a significant source of invertebrate food for fish and a source of large woody debris and thus form an important habitat component for these fish species.

Invertebrates: Listed invertebrates are provided only as long lists for the entire province. Interpreting which invertebrates are tied to hardwood dominated stands is beyond the scope of this work.

Table 6. The use of hardwoods by red and blue listed species.

Species	Age Class 1+2 0-40 years	Age Class 3-4* 41-80 years	Age Class 5-8** 81-250 years
Fisher			[use large cavities as natal nests]
S. T. Grouse		[winter cover and feeding]	[winter cover and feeding]
W. Screech Owl			[feeding and cavity nesting]
Lewis's woodpecker			[cavity nesting near grasslands]
Great Blue Heron*			[canopy nesting close to water]
Bull Trout			[important habitat element]
Cuttrout Trout			[important habitat element]

* Riparian obligate species are indicated in *italics.*

4.3 AN INVENTORY OF HARDWOODS USING FOREST COVER DATA

4.3.1 THE REGIONAL DISTRIBUTION OF HARDWOODS

As part of this project we developed maps showing the distribution of hardwoods across the Basin at the 1:250,000 map scale. An example of these maps is provided below (Figure 2.). Maps of hardwood distribution by Forest District (with two maps for the Columbia Forest District) are provided in the CD-ROM version of the report only. These maps are in Adobe Acrobat PDF format; the data in ARCINFO format is available through the CBFWCP, Nelson office.

It is difficult to make any generalizations about the present distribution of hardwoods except to note the following:

- Hardwoods are widely distributed across the study area and occur in all BEC units although they are uncommon in the ESSF.
- A striking feature is the degree to which the three species' distributions overlap. There are many areas which support a mix of cottonwood, aspen and birch. This is probably indicative of their similar response to disturbance and site type.
- Cottonwoods occur primarily in riparian areas in the drier portions of the region (Cranbrook and Invermere Forest Districts). All stands that contain > 80% cottonwood are in riparian floodplain areas, mostly along the major rivers. Smaller stands occur on alluvial portions of several secondary rivers such as the St. Mary's, Elk, Moyie, Duncan, Salmo, Slocan, Horsethief, Goldstream, Illecillewaet, Inconappleux, Inakoklin and Akolkolex Rivers.
- Stands dominated by aspen (>80%) occur throughout the study area, especially in the Robson Valley, Golden area, Elk Valley and the Trail area.
- Stands dominated by birch (>80%) are very rare.
- The distribution of present day hardwood stands suggests that hardwoods in general and aspen in particular, are most common in areas with a long history of human activity (Robson Valley, Seaton Creek in the Slocan, the Trail area and the Elk Valley). Early miners burned most of these areas either accidentally or to expose bedrock for prospecting. Sparks from early coal-burning trains were also a major factor in starting fires in some of these areas. Most hardwood stands in these areas are on fire-prone sites, especially south and west-facing slopes.

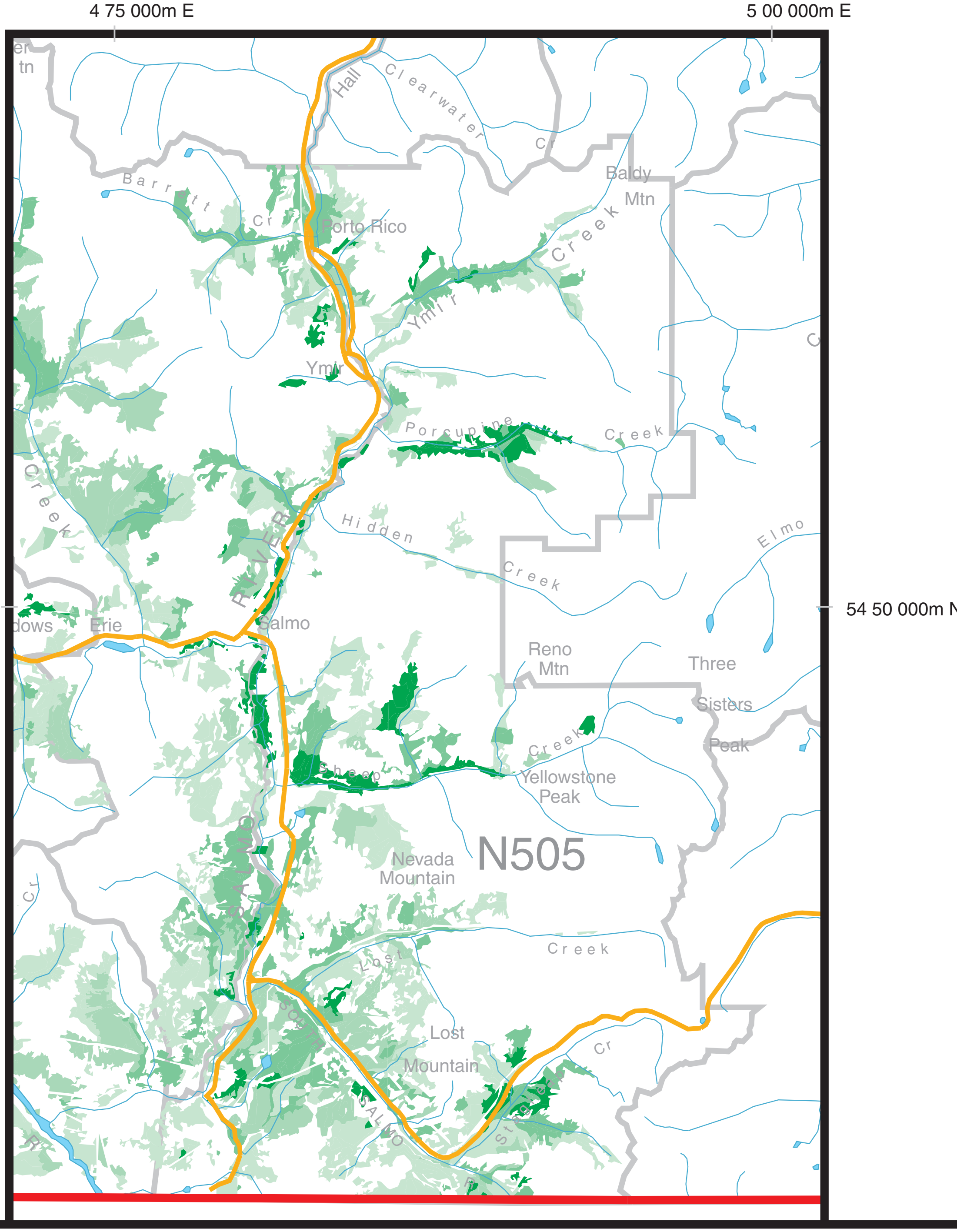


Figure 2. Hardwood presence in the Salmo River area.

Rank 1 Layer: Percent Class (ha)

- >80%
- >40% and <=80%
- >20% and <=40%
- >0% and <=20%

Program Area Boundary

Landscape Unit Boundary

0 5 10 15 km

Scale 1:250,000

Production Date: June 05, 2001

4.3.2 THE DISTRIBUTION OF HARDWOODS BY FOREST DISTRICT

Table 7 shows the area of all three hardwoods species in each Forest District. It also indicates what proportion of all hardwood stands is found in the <20%, 21-80% and >80% categories. Stands with a minor hardwood component (1-20%) make up the majority of hardwood presence (280,058 ha (54.0%)). The mixed hardwood stand type (21-80%) cover 184,477 ha (35.6%) and pure hardwood stands (>80%) cover 54,184 ha (10.4%).

Table 7. The proportion of all hardwoods in stands where hardwoods are a minor component (1-20%), in mixed stands (21-80%), and in pure stands (>80%).

Forest District	(>80%) ha	%	(21-80%) ha	%	(1-20%) ha	%
Arrow FD	11333.9	7.9%	56185.0	39.2%	75706.0	52.9%
Cranbrook FD	6382.6	9.0%	21658.0	30.6%	42782.0	60.4%
Golden FD	7589.1	16.7%	16911.0	37.2%	20969.0	46.1%
Invermere FD	2836.7	4.5%	16053.0	25.7%	43658.0	69.8%
Kootenay L. FD	6294.9	8.0%	27506.0	35.0%	44781.0	57.0%
Revelstoke FD	873.5	2.4%	13133.0	36.8%	21723.0	60.8%
Robson V. FD	18873.4	22.9%	33031.0	40.1%	30439.0	37.0%
Total	54184.0	10.4%	184477.0	35.6%	280058.0	54.0%

In total, hardwood stands, including stands with a mix of hardwood species, make up 10.8 % of the total forested area of the study area, as below.

Table 8. Total ha of hardwood stands in the study area.

Stand Type	All Hardwood stand Ha	% of forested area
>80% hardwood stands	54,184.0	1.1%
21-80% hardwood stand	184,477.0	3.9%
<20% hardwood stands	280,058.0	5.8%
All stands	518,719.0	10.8%

Although pure hardwood stands are a minor part of the overall forest environment in the study area, (54,184 ha) stands with a hardwood component (1-80%) cover a significant area (464,535 ha).

Table 9 indicates the area of stands with a hardwood component in each Forest District. Such stands make up 14.7% of Arrow forest district with lesser percentages found in other districts.

Table 9. The total area of forest stands that have a hardwood component in each Forest District.

Forest District	Ha of stands with a hardwood component	% of forested area
Arrow FD	143225.6	14.7 %
Cranbrook FD	70823.1	7.3 %
Golden FD	45470.7	12.8 %
Invermere FD	62548.8	9.6 %
Kootenay L. FD	78581.9	10.1 %
Revelstoke FD	35729.3	8.9 %
Robson V. FD	82342.7	12.6 %
Total**	518722.1	10.8%

* Proportion of the forested area of the Forest District, not the entire area (including alpine, grassland, etc.)

** These data do not correspond exactly to the data in Table 7 since some stands with a mix of hardwoods would be included here (a 70% aspen stand with a 20% birch component would enter the >80% category).

Table 10 provides an overview of the total ha of stands that contain each of the hardwood species in each forest district. Stands that contain cottonwood are a minor component in all forest districts (<1.8%) except the Robson Valley Forest District where they make up 2.9% of stands. The proportion of stands that contain aspen vary from 11.7% in the Golden FD to 3.6% in the Revelstoke FD. The proportion of the forested area with a birch component is smaller, ranging from .8 % to 7.2%.

Table 10. The area of forest stands that contain each hardwood species.

Forest District	Cottonwood ha	% of For. Area*	Aspen ha	% of For. Area*	Birch ha	% of For. Area*
Arrow FD	15532.0	1.6%	83796.6	8.6%	70720.4	7.2%
Cranbrook FD	17907.4	1.8%	55742.2	5.7%	7936.7	0.8%
Golden FD	5739.1	1.6%	41527.1	11.7%	3996.9	1.1%
Invermere FD	5084.9	0.8%	51271.0	7.9%	14822.8	2.3%
Kootenay L. FD	6958.8	0.9%	44814.6	5.8%	40024.3	5.2%
Revelstoke FD	6601.4	1.6%	14538.9	3.6%	22332.4	5.5%
Robson V. FD	19196.7	2.9%	64361.3	9.8%	30739.7	4.7%
Total	77020.4	1.6%	356051.5	7.4%	190573.2	4.0%

* Proportion of the forested area of the Forest District, not the entire area (including alpine, grassland, etc.)

Table 11 indicates the proportion of hardwood stands that are pure stands (>80%). Pure cottonwood stands are more common in the Invermere and Kootenay Lake districts while aspen stands in this class are most common in the Golden and Robson Valley forest districts. Birch stands of >80% are very rare and make up a very small proportion of all birch stands (1.5%).

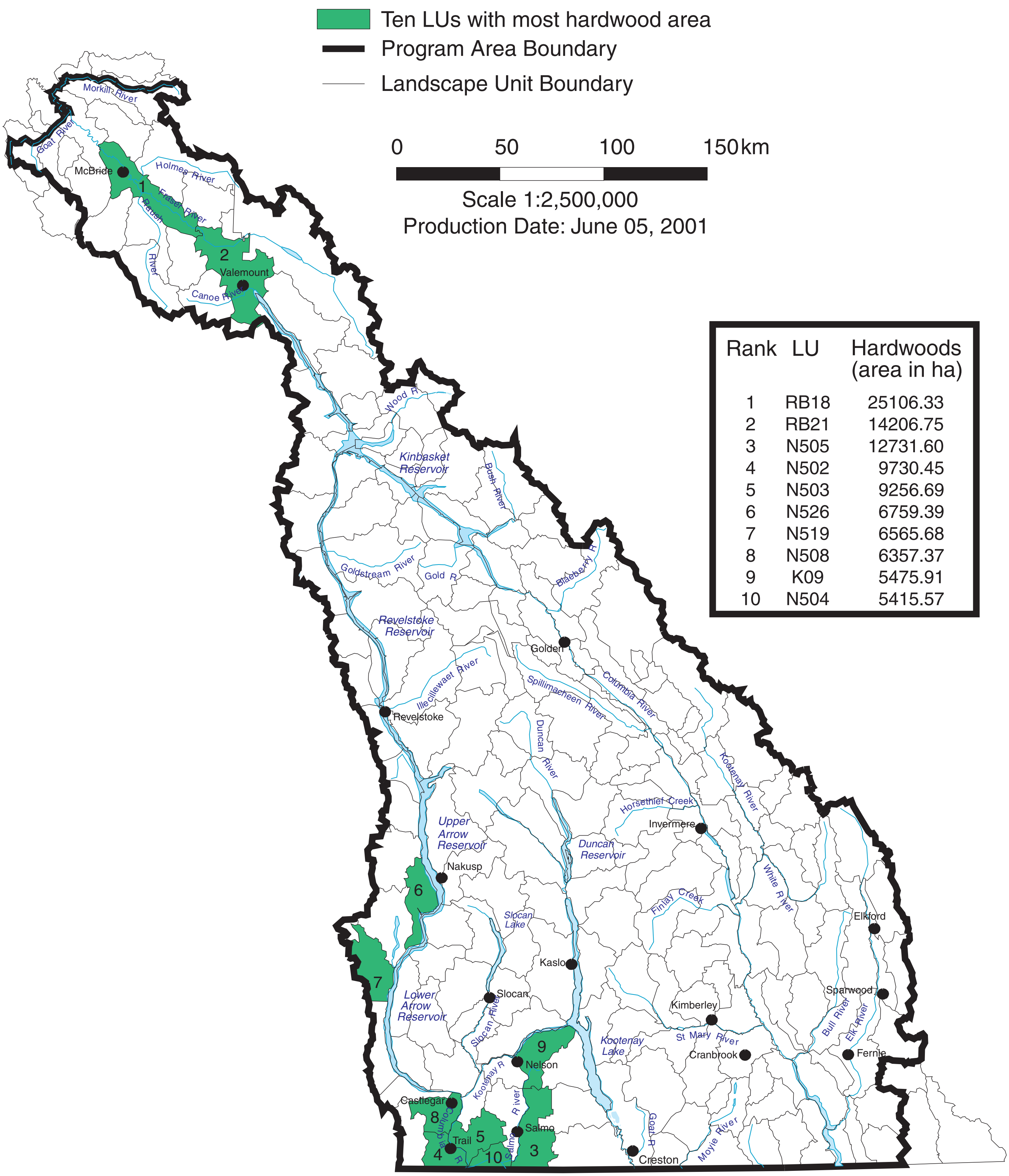
Table 11. The area of forest stands with a >80% hardwood component in each Forest District.

Forest District	Cottonwood Total Ha	% of all ct stands	Aspen Total ha	% of all aspen stands	Birch Total ha	% of all birch stands
Arrow FD	925.13	6.0%	4043.09	4.8%	867.16	1.2%
Cranbrook FD	982.79	5.5%	2348.79	4.2%	30.06	0.4%
Golden FD	260.94	4.5%	6374.21	15.3%	69.24	1.7%
Invermere FD	535.68	10.5%	1414.20	2.8%	116.36	0.8%
Kootenay L. FD	1220.36	17.5%	1836.52	4.1%	923.71	2.3%
Revelstoke FD	151.05	2.3%	37.07	0.3%	393.74	1.8%
Robson V. FD	752.19	3.9%	8319.37	12.9%	367.84	1.2%
Total	4828.14	6.3%	24373.25	6.8%	2768.11	1.5%

4.3.3 THE DISTRIBUTION OF HARDWOODS BY LANDSCAPE UNIT

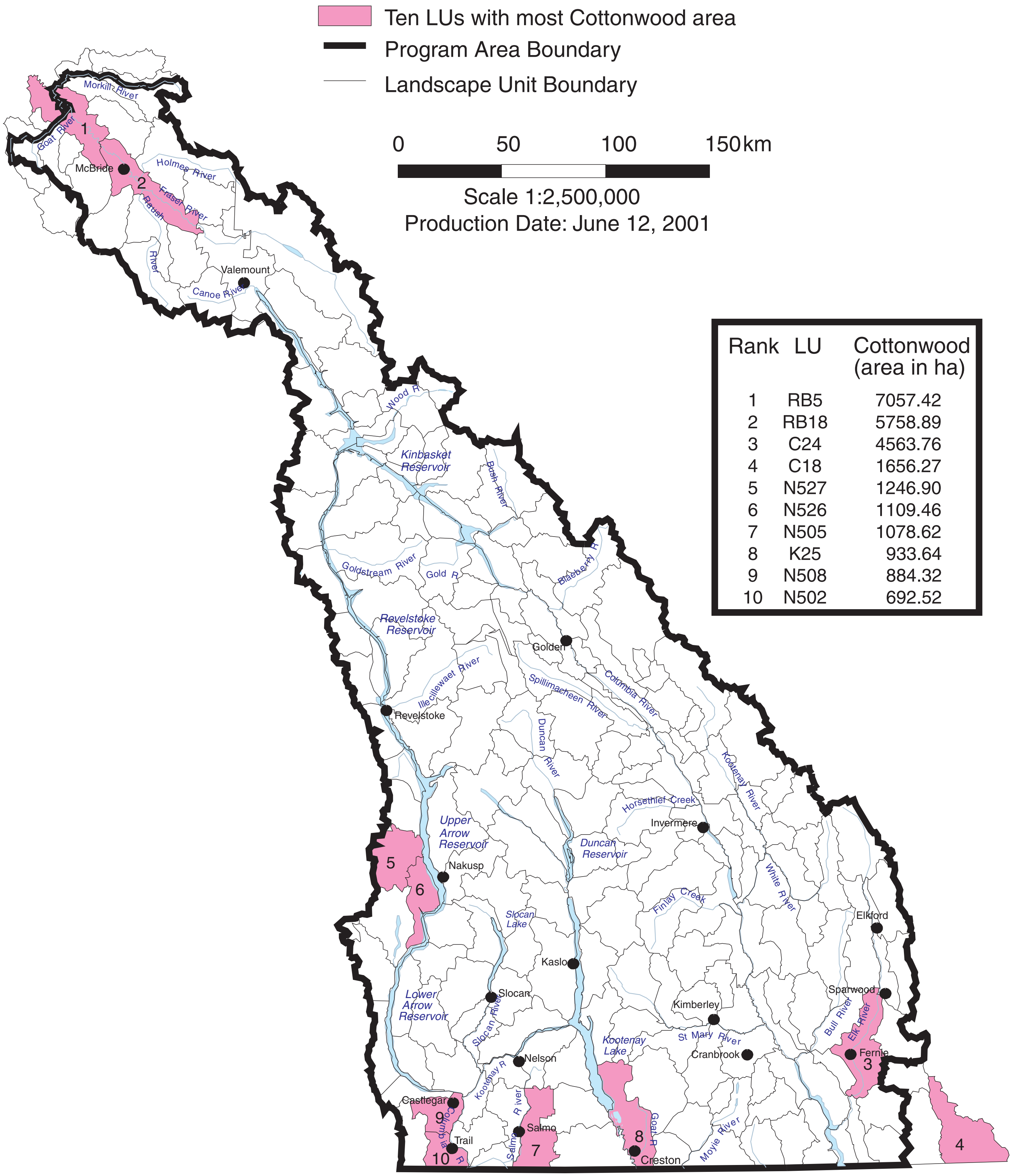
Figure 3 indicates the ten landscape units in the study area that had the largest area with hardwood presence within the CBFWCP area. This information suggests that hardwoods are concentrated in the Robson Valley, the Golden area and in portions of the Arrow Forest District. Figures 4, 5 and 6 indicate the ten landscape units with the greatest area of stands containing cottonwood, aspen and birch. Total cottonwood stand areas are found in LUs with a combination of riparian and upland stands of cottonwood in all but the two units in the Trail area. LUs with large aspen stand areas are found in the Trail to Salmo area, Golden area and the Robson Valley. One LU is located near Invermere. LUs with large birch stands occur primarily in the Arrow Lakes Forest District with other units in the Robson Valley, the Revelstoke area and along Kootenay Lake.

Figure 3. The ten landscape units with the largest area of hardwood presence in the CBFWCP area.



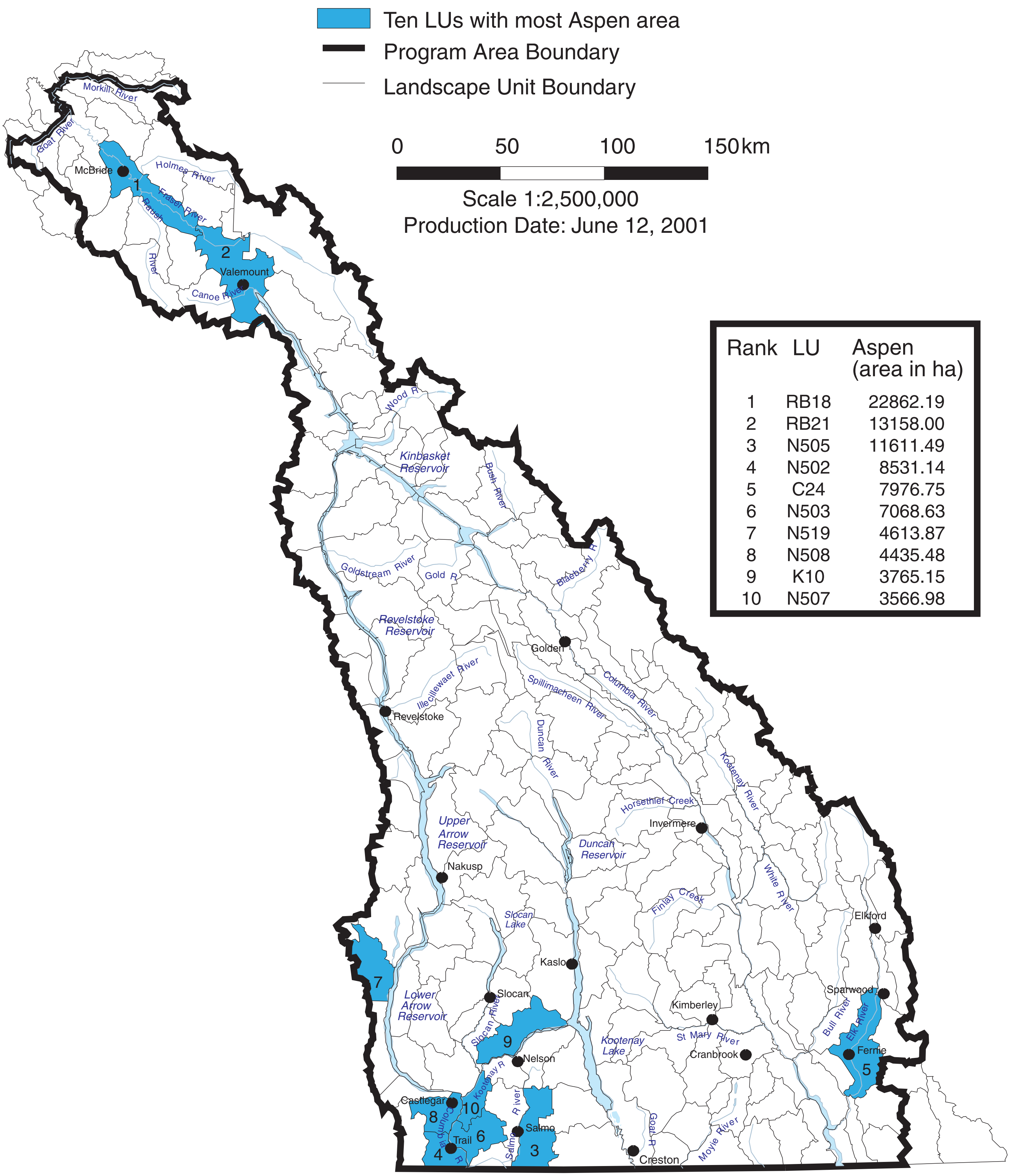
Rank	LU	Hardwoods (area in ha)
1	RB18	25106.33
2	RB21	14206.75
3	N505	12731.60
4	N502	9730.45
5	N503	9256.69
6	N526	6759.39
7	N519	6565.68
8	N508	6357.37
9	K09	5475.91
10	N504	5415.57

Figure 4. The ten landscape units with the largest area of cottonwood presence in the CBFWCP area.



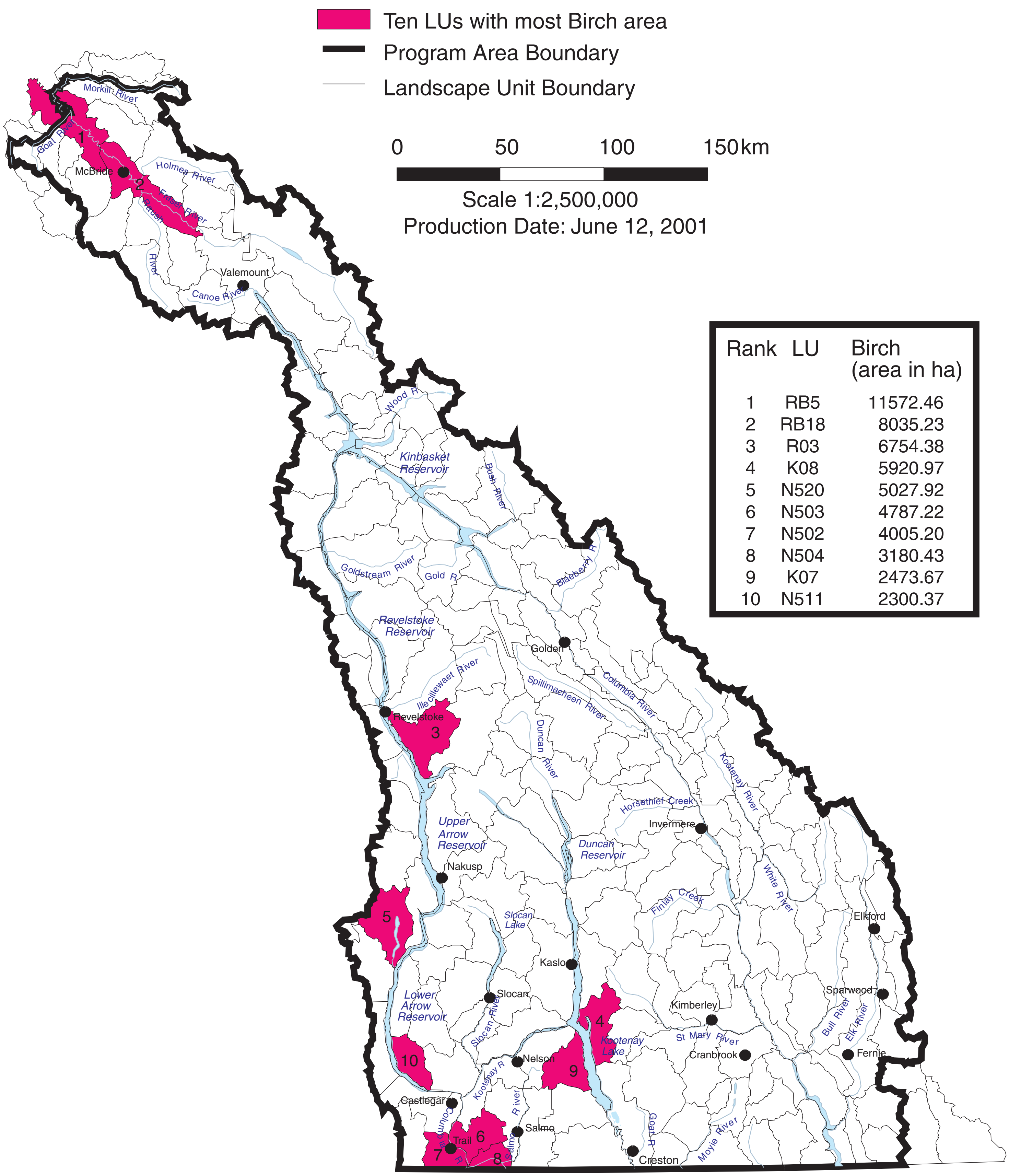
Rank	LU	Cottonwood (area in ha)
1	RB5	7057.42
2	RB18	5758.89
3	C24	4563.76
4	C18	1656.27
5	N527	1246.90
6	N526	1109.46
7	N505	1078.62
8	K25	933.64
9	N508	884.32
10	N502	692.52

Figure 5. The ten landscape units with the largest area of aspen presence in the CBFWCP area.



Rank	LU	Aspen (area in ha)
1	RB18	22862.19
2	RB21	13158.00
3	N505	11611.49
4	N502	8531.14
5	C24	7976.75
6	N503	7068.63
7	N519	4613.87
8	N508	4435.48
9	K10	3765.15
10	N507	3566.98

Figure 6. The ten landscape units with the largest area of birch presence in the CBFWCP area.



Rank	LU	Birch (area in ha)
1	RB5	11572.46
2	RB18	8035.23
3	R03	6754.38
4	K08	5920.97
5	N520	5027.92
6	N503	4787.22
7	N502	4005.20
8	N504	3180.43
9	K07	2473.67
10	N511	2300.37

4.3.4 THE DISTRIBUTION OF HARDWOODS ON PRIVATE AND CROWN LAND.

Although we did not assess the distribution of hardwoods between private and crown lands, volume data from Fraser and Davis (1996) indicates that a large proportion of hardwood volumes are on private land (Table 12). In all forest districts except Revelstoke, >25% of cottonwood stands are located on private land. The figures are also high for aspen and birch. This is a reflection of the predominance of hardwoods at low elevations in major valleys where most private land is found. It is important to note that 85% of hardwood timber harvested in the early 1990's came from private land (Fraser and Davis 1996).

Table 12. The volume and proportion of hardwood volume on private land (Fraser and Davis 1996).

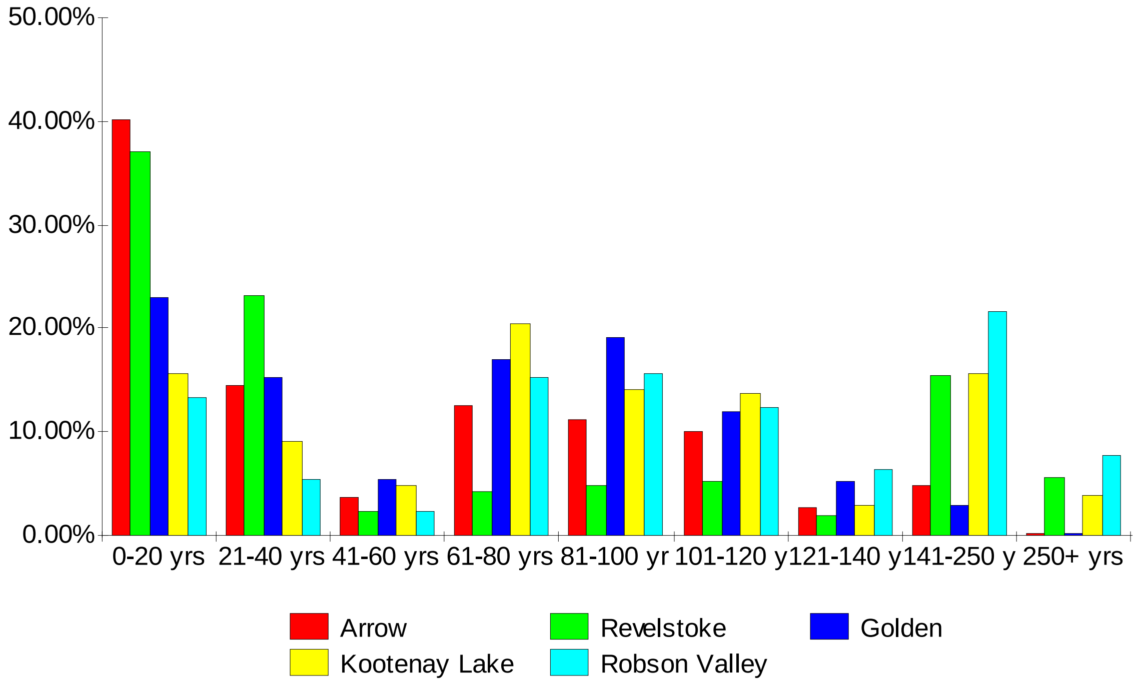
Forest District	Cottonwood M^3 on private land	% of total volume	Aspen M^3 on private land	% of total volume	Birch M^3 on private land	% of total volume	All Hardwoods	% of total volume
Arrow FD	171294	48.50%	320507	15.62%	277912	18.27%	769713	19.61%
Kootenay L. FD	129483	41.22%	181502	15.92%	255582	24.55%	566667	22.71%
Cranbrook FD	211191	39.00%	196588	26.26%	14071	22.43%	421850	31.18%
Invermere FD	25647	25.04%	148921	20.70%	26090	39.88%	200658	22.62%
Golden FD	26505	28.42%	278638	25.27%	13789	33.58%	318932	25.79%
Revelstoke FD	6043	9.62%	28886	8.38%	65414	13.99%	100343	11.47%
Robson V. FD	no data							
Total	570163	38.78%	1155042	18.91%	652858	20.41%	2378163	22.07%

4.3.5 THE AGE-CLASS DISTRIBUTION OF HARDWOODS BY FOREST DISTRICT.

The age-class structure of hardwood stands was analyzed by landscape unit and forest district using the Forest Cover database. The landscape unit data, for all forest districts and all species, is provided in Excel format on the CD version of the report.. A summary of this data, by Forest District, is provided below.

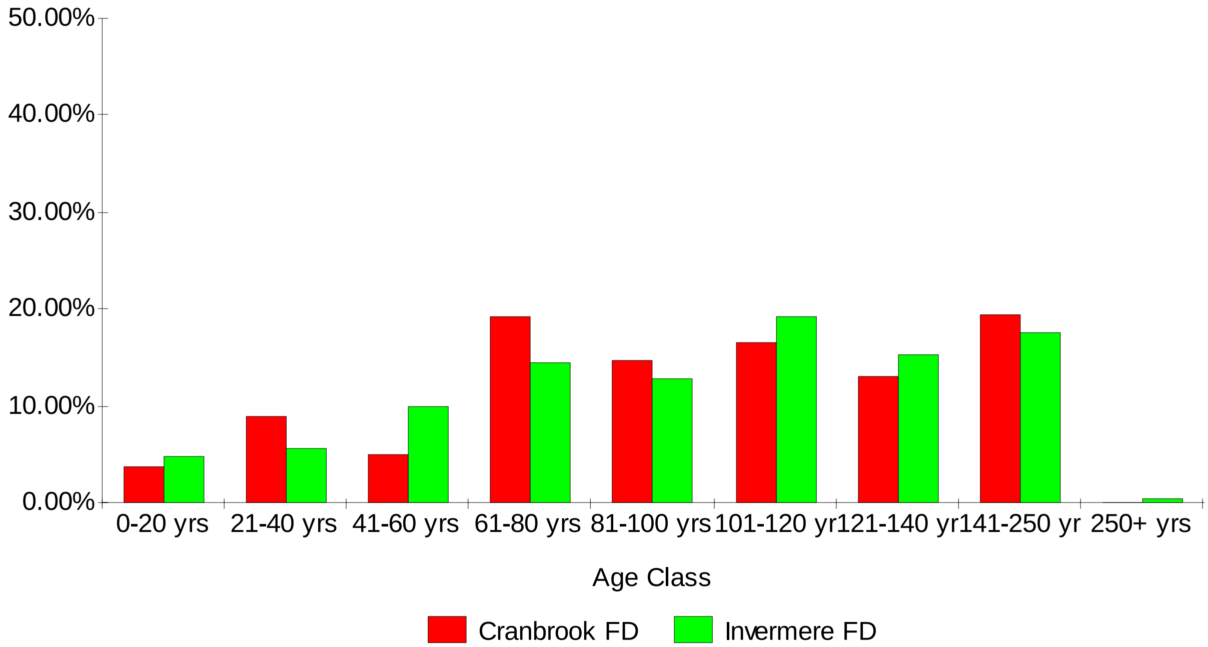
Figures 7 shows that extensive cottonwood recruitment has occurred in recent years in the forest districts in the wetter portions of the study area, especially in the Golden, Arrow and Revelstoke areas, primarily as a result of cottonwood recruitment in logging blocks. These data also suggest that there was little cottonwood recruitment in the 1940 to 1960 era (Age Class 3) in all five of these forest districts.

Figure 7. Age class data for cottonwood in the Arrow, Kootenay Lake, Robson Valley forest districts and the Revelstoke and Golden areas.



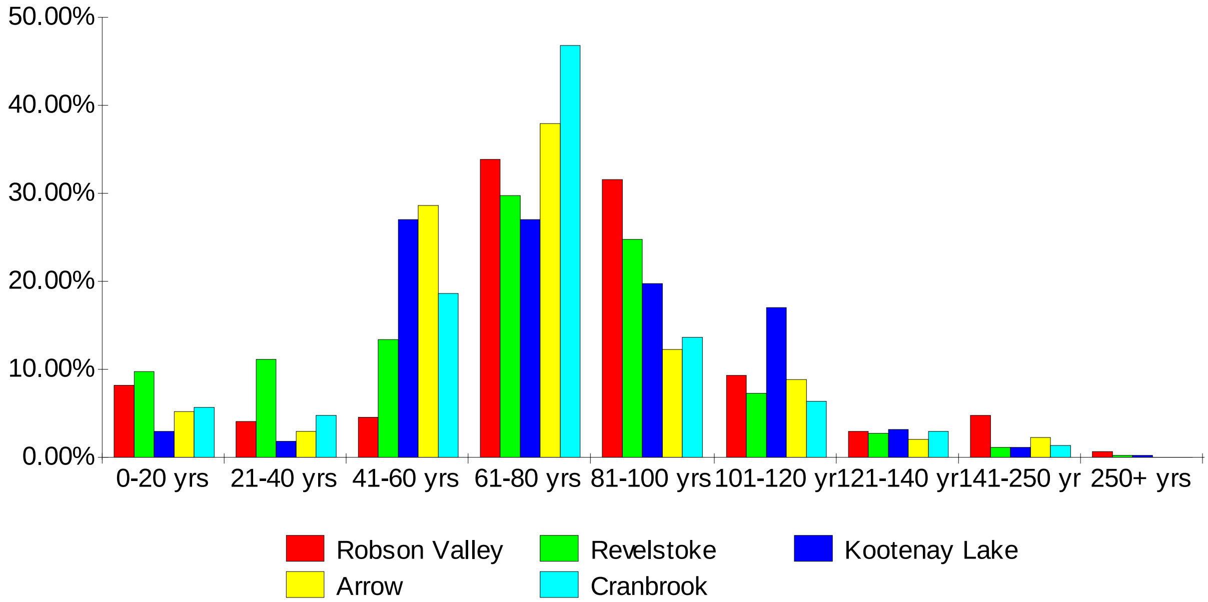
Figures 8 indicates the age class structure of cottonwood stands in forest districts dominated by drier biogeoclimatic zones (Cranbrook and Invermere). There would appear to be minimal cottonwood recruitment in these forest districts. Most cottonwood stands in these forest districts are in riparian areas (see mapping in Appendix III.). Little logging occurs in riparian areas in these Forest Districts (T. Volkers, pers. comm.) and as a result it seems that there are few younger age stands that show up in the forest cover data. Younger cottonwood stands may be under-estimated as younger age stands of cottonwood along rivers resulting from fluvial processes tend to be very narrow (<10m) and are not picked up in forest cover mapping.

Figure 8. Age class data for cottonwood in the Cranbrook and Invermere Forest Districts.



Figures 9 and 10 indicate the age class structure of aspen by forest district. Figure 9 shows that some recruitment of aspen has occurred in recent years in most forest districts. Recruitment is low in the Cranbrook, Arrow and Kootenay Lake forest districts where <6% of stands are 0-20 years. More recruitment is occurring in the Robson Valley (8.15%) and in the Revelstoke area, although aspen stands in this area are minimal (Table 10). It is notable that almost 50% of stands in the Cranbrook forest district are in the 61-80 year age class. (A similar age class structure occurs for birch in this forest district (Figure 12). The presence of aspen in age classes 8 and 9 (>140 years) is likely an artifact of the forest cover database, as explained earlier.

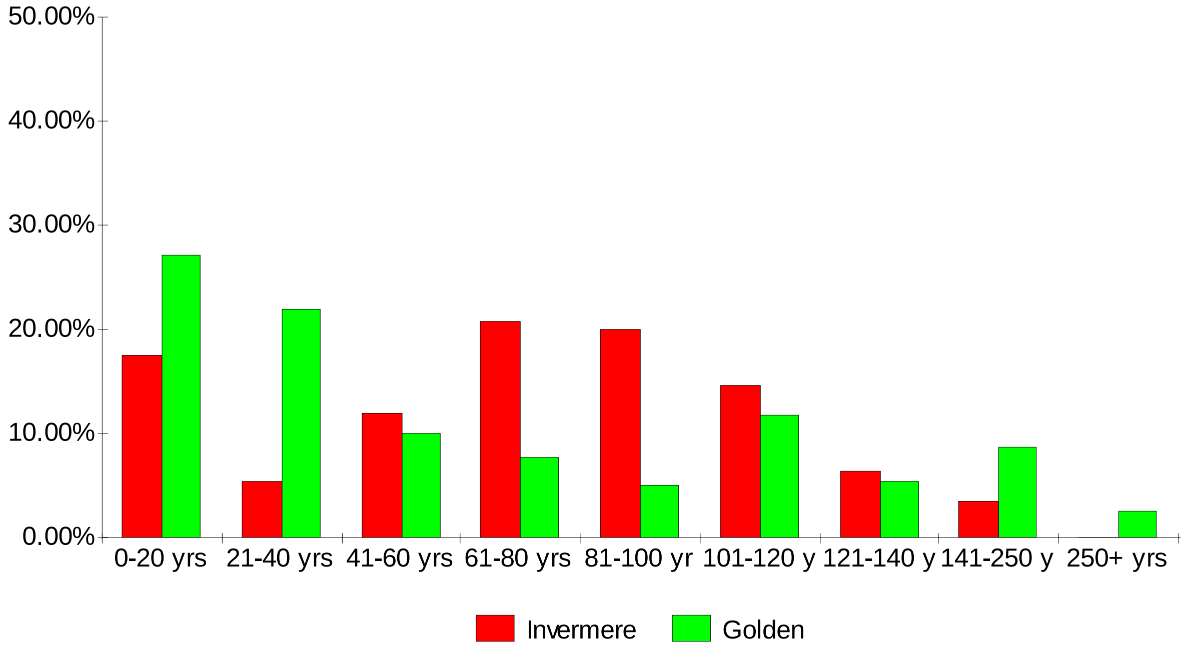
Figure 9. Age class data for aspen in the Arrow, Cranbrook, Kootenay Lake, Robson Valley forest districts and the Revelstoke area.



More extensive areas of recruitment have occurred in recent years in the Invermere and Golden areas (Figure 10), due in part to hardwood recruitment in recent fires in the Trench (Findlay Creek bench, north west of Invermere near Lake Enid and in the Sue fire area north of Golden). (See the distribution maps on the CD-ROM version of the report.). Recruitment is also occurring in clear-cuts in these districts (D. Monchak, pers. comm.).

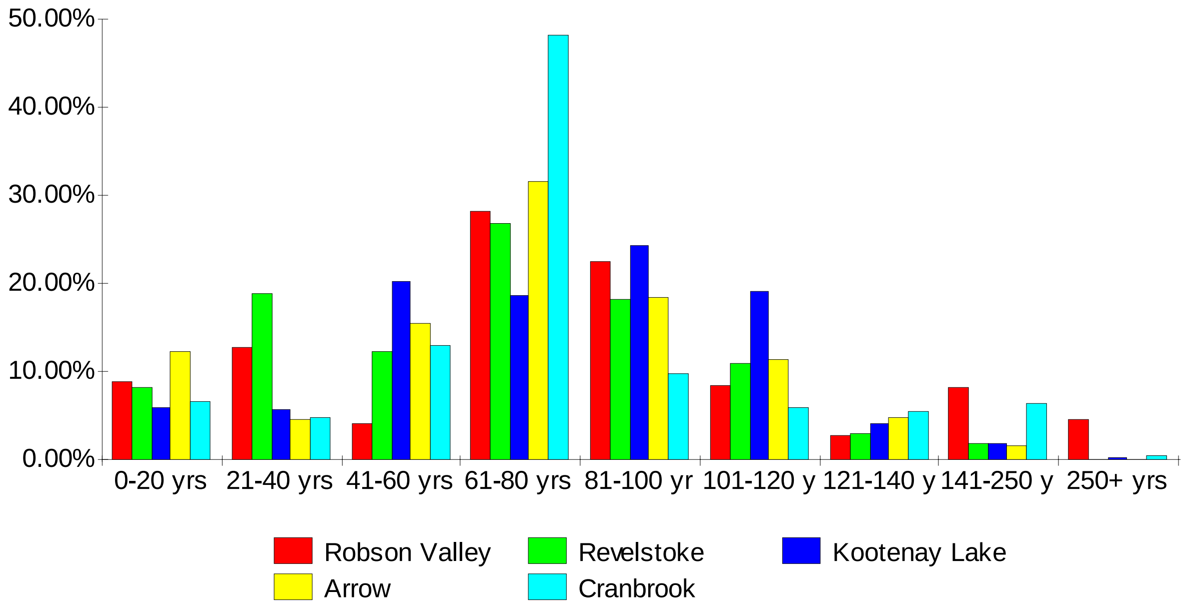
Data for aspen stands in two national parks presents a slightly different picture (Kay 1997a). Elk browsing and fire control in Kootenay and Yoho National Parks have created a very uneven age class structure in aspen stands there. No recruitment has occurred for 40 years and only 2% of stands there were in the 41-60 year age class. 89% of aspen stands in these parks were between 61 to 120 years of age. This scenario of early recruitment being limited in extent by fire management and suckering being suppressed by elk browsing likely occurs in many other areas, but has not been documented.

Figure 10. Age class data for aspen in the Invermere and Golden Forest Districts.



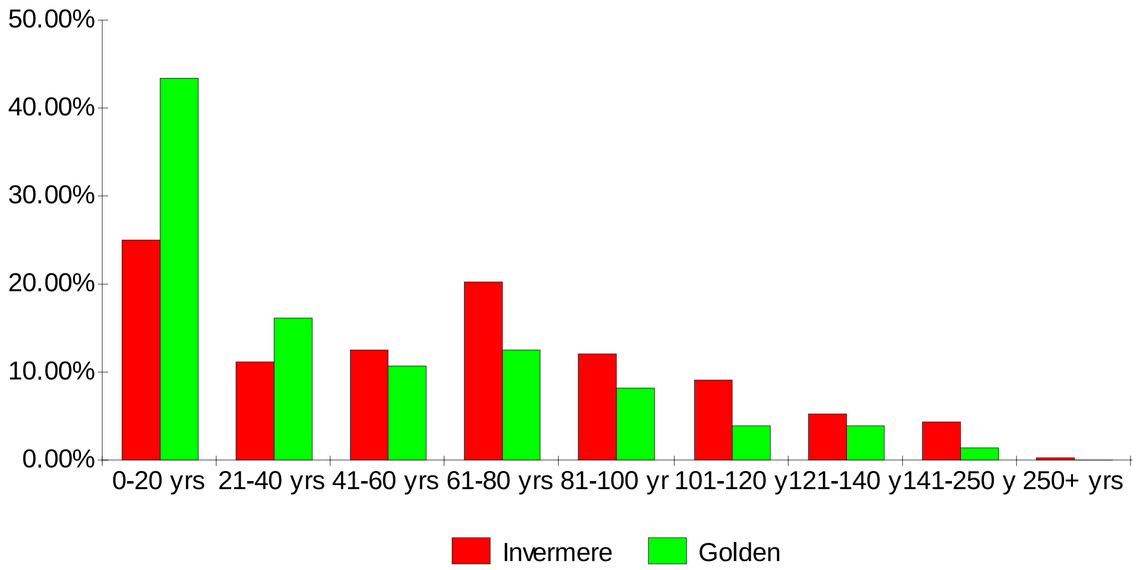
Age class data for birch provides a picture similar to that found for aspen. Figure 11 provides age class data for the same five forest districts as in Figure 9 for aspen. As with aspen, almost 50% of the birch in the Cranbrook forest district is in age class 61-80 years. All the forest districts have <9% in age class 1-20 years except for the Arrow forest district with 12.33%.

Figure 11. Age class data for birch in the Cranbrook, Kootenay Lake, Arrow, Robson Valley Forest Districts and the Revelstoke area.



Again, as with aspen, the Invermere and Golden areas show a much larger component of birch recruitment in the 1-20 year age class (Figure 12).

Figure 12. Age class data for birch in the Invermere Forest District and Golden area.



These data are provided in Excel format by landscape unit on the CD-ROM version of the report. From such data it is apparent that disturbance history is expressed at a scale larger than the landscape unit level. Although age class data for each forest district show a reasonable distribution of stands in all age classes, at the landscape level one finds many landscape units where only one or two age classes occur. This suggests that maintaining stands in all age classes within single landscape units may be difficult except in units where hardwoods are well represented.

4.4 AN OVERVIEW OF HARDWOOD STAND MANAGEMENT STRATEGIES

We have provided below a review of policies and management actions that relate to hardwoods. Appendix V. lists the researchers and managers contacted.

4.4.1 REGIONAL LAND USE PLANNING

Kootenay Boundary Land Use Plan: There does not seem to be any direct mention (R. Neil., P Davidson, pers. comm.) of hardwood stands in the Kootenay Boundary Land Use Plan. Most policy decisions related to hardwoods are the result of management decisions made prior to the land use planning process (such as removing hardwoods from the AAC in Cranbrook FD) that have been included in overall planning and the Higher Level Plan (T. Volkers, pers. comm.).

Robson Valley Land and Resource Management Plan: A LRMP was developed for the Robson Valley in 1999. As part of the LRMP, the valley bottom has been designated as a Resource Emphasis area for agriculture and settlement, while the sides of the valley have been designated as Special Management Zones. Both of these areas contain substantial stands of hardwoods. The latter designation was driven primarily by visual quality concerns (M. van der Gomma, pers. comm.).

Protected Areas: Few of the protected areas established by the land use planning process support extensive hardwood stands. There is one new protected area (West Twin) that spans the Robson Valley 20 km downstream of McBride that includes some hardwood stands.

Special Management Zones: Although SMZs play a role in other regions of the province, (Special Management Zone Working Group 2001) in relation to hardwoods, SMZs have been de-emphasised in the Nelson Forest Region in lieu of caribou, grizzly bear, ungulate winter range and other less spatially directed guidelines. The role of SMZs in the Robson valley as part of the LRMP for that area may be an exception.

Community Forests: Three are several community forests in the study area, however they contain relatively few hardwood stands (J. Smith, D. Williams, pers. comm.).

Biodiversity Guidebook: The Biodiversity Guidebook (BCMOF and BCMOELP 1995) makes the following reference to hardwoods:

> ***"Tree Species Diversity:*** *An ecologically appropriate variety of tree species, including hardwoods, should be maintained in a stand. Tree species composition will be managed by choice of silvicultural system, harvesting, site preparation, planting, regeneration and stand tending activities."*

Based on discussions with managers, this policy is being pursued across the study area.

Regional AAC Mitigation Strategy: As part of the regional AAC mitigation strategy, the idea of converting hardwoods stands to conifer stands has been proposed as a means to increase the productive forest land base and eventually, the annual allowable cut, in some forest districts. If this approach were taken, it would have major implications for hardwoods in those districts. This idea has been discussed as part of the Innovative Forest Practices Agreement (P Jekins, pers. comm.) for the Arrow forest district. In the Kootenay Lake forest district there has been some discussion of converting stands on an experimental basis but no action has occurred to date (M. Knapik, pers. comm.). In the Golden area, the replacement of old hemlock stands is being considered for conversion but the replacement of hardwood stands has not (Bob Richkum, pers. comm.).

Potential Hardwood Harvest: There is little interest in hardwood harvest except as salvage associated with conifer harvest. Fraser and Davis (1996) provide a discussion of the reasons for this lack of interest. Dave Claperton, silviculture zone forester for the Golden area, indicated that they have tested aspen in that area and found it was of very poor quality with high levels of heartwood rot. In the Robson Valley area, there is a separate cut allocation of 6000 m^3 for hardwoods, but it has not been utilized to date.

Environmental Accounts: The “budgets” for old growth and mature forest and the biodiversity emphasis areas are contained in the Higher Level Plan adapted in 1999. This document contains no explicit discussion of hardwood stand requirements. Hardwood requirements will have to fit into the landscape unit planning process described below.

4.4.2 FOREST DISTRICT LEVEL PLANNING

Landscape Unit Planning: In the Landscape Unit planning process, there is a budget allocated for areas to remain in older age class stands and mature age class stands, depending on the biodiversity emphasis given to each landscape unit. It appears that old growth management areas (OGMAs) are being treated as something close to protected area status, with the expectation that these old growth areas will not shift around on the landscape to any significant degree. These areas therefore will eventually develop into older age conifer forests with a relatively minor component of hardwoods in most areas provided by gap dynamics in these stands. Most of these OGMAs are being located in inoperable areas (O. Thomae, pers. comm.), and have minor hardwood components. The mature component is handled in a similar manner but on a shorter rotation and it seems likely that the location of mature stands will move across the landscape in a more dynamic manner. These may be of value for hardwoods, in terms of retaining some hardwood stands in rotations > 90 years to allow larger bole size development and a longer period during which cavity nesters can use hardwood trees. Snag development will also occur under these longer rotations. A detailed analysis of hardwood distribution in relation to biodiversity emphasis was beyond the scope of this work, however it appears that most hardwood stands will occur outside the mature and old growth areas and will have to be considered in the portions of the landscape that will be managed on a 80 to 100 year rotation.

Innovative Forest Practices Agreements: The importance of hardwood stands in the Arrow Forest District was discussed in Bunnell (2000) and hardwoods are being considered as part of the IFPA process in that forest district. Proposals have been made to convert these areas to conifer stands. How they will be managed will be considered as part of the sustainable forestry framework that is presently being developed. No decisions have been made to date (P. Jeakins, pers. comm.).

Enhanced Forest Management Pilot Projects: Hardwoods are a minor component in forests in the pilot area (White River) and have not been considered except as identified in Kari's Stuart-Smith's research on bird use (G. Anderson, pers. comm.).

We found no data to suggest that hardwoods are being considered in Results-Based Forest Practices Code Pilot Projects or Forest Certification processes.

NDT4 restoration planning: Hardwoods have not being considered directly in this process (O. Tomae, pers. comm.). Hardwoods are grouped with shrub-lands in the analysis of options for restoration. This component will remain as the same percentage of land base in the long term. Some of the managers involved in this project have been considering how best to manage for hardwoods (primarily aspen) in the restoration process (O. Tomae, P. Davidson, pers. comm.).

Harvest strategies: During harvest, hardwoods are often left standing, based on the assumption that doing so will maintain hardwoods and related wildlife values on the site. This may not be the case when considered over the long term. The stems retained will remain in the stand for the duration of their life cycle. They will reach old age when the conifer stand that has grown up around the stem is in middle age. Any suckering from the older hardwood stems will then have to compete within a well established conifer stand and are unlikely to survive. It seems that slashing of hardwoods at harvest, though counter-intuitive, could be a useful strategy for maintaining hardwoods, since the suckers or seedlings so generated would be competing in a stand of young conifers. Peter Davidson of MOELP and Steve Byford of the Cranbrook Forest District have recognized this problem. They are suggesting that half the hardwood stands be slashed in this kind of situation to allow for hardwood presence throughout the rotation.

Silviculture strategies: Hardwoods are well distributed across the Basin at present and constitute a "silviculture problem" in many areas. When stands with a hardwood component are harvested, sucker or sprout development by all three species and establishment from seed for at least cottonwood and birch have resulted in a substantial hardwood component in many young stands, especially in wet belt areas. This has been an area of substantial interest on the part of forest managers. Delving into this area in depth is beyond the scope of this report, but we have made the following observations.

- The "free to grow" requirements result in conifers being established much earlier in the seral sequence than they would under natural conditions. This provides conifers with a competitive advantage that may have long-term consequences for maintaining hardwoods as a component in forest stands in some areas. However, the post harvest "free-growing" guidelines now allow for 400-1000 hardwood stems per hectare of the same size as the conifer crop (Mike Madill, pers. comm.). These regulations are based on stems/50m^2 and thus allow for a good distribution of hardwood stems across a block. The stems/50m^2 left vary for species and BEC unit with lower numbers in wetter sub-zones and variants.

Details on these guidelines are available at: **http://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/free/free4/neltoc.htm**.

- During stand tending, up to 50 stems per ha of hardwoods can be left under current guidelines (reference?). In many areas, larger stems (>15cm) are being left (Dave Claperton, pers. comm.). However, this area is primarily a company responsibility now. It was beyond the scope of this project to consult with the company foresters actually carrying out stand tending projects.
- Herbicides have been used in some parts of the province to reduce competition between young hardwoods and conifers. This kind of action is now very rare in the CBFWCP area. No herbicides have been applied in the Cranbrook Forest District for 14 years (T. Volkers, pers. comm.). Public concern has limited the use of herbicides through most of the study area and most silvicultural thinning is done by slashing (B. Fraser, pers. comm.).
- Slashing to reduce competition from hardwood trees and shrubs is used in the study area. Based on discussions with several managers, it appears that only 5-15% of stands are being treated in this way.
- There is a potential role for hardwoods as nurse trees for establishing spruce stands, such as has been attempted in some areas in the Robson Valley. Birch can also play a role in managing Armillaria root disease. Substantial research has been conducted on this subject by S. Simard and others of the B.C. Ministry of Forests Research Branch.
- Several studies have looked at various silvicultural treatments and their impact on birds and small mammals (Steventon et al. 1998, Runciman and Sullivan 1996, Sullivan et al. 1998a, 1998b, Beese and Bryant 1999, Bryant 1994, Trebra et al. 1998). Easton and Martin (1998) examined the impact of removing hardwood trees in young conifer plantations. They found that glyphosate (herbicide treatment) removed hardwoods more effectively than manual slashing and had an impact on nesting success. Steventon et al. (1998) looked at the impact of partial felling (30 and 60%) on bird communities. None of the studies we reviewed looked at the implications of such actions on the long-term presence of hardwoods, or related wildlife species, within stands.

4.5 HARDWOOD STAND TYPES OF MANAGEMENT CONCERN

Although the distribution of most conifer species is defined by BEC unit, this does not seem to be the case for hardwoods. The distribution of these species is related primarily to site condition and disturbance rather than BEC unit. In other words, cottonwood occur in riparian areas, irrespective of climatic regime or BEC. Aspen occur is areas with a long history of disturbance, again, irrespective of BEC unit. Birch occur on wet sites in all BEC units. All three species occur where disturbance and relatively moist site come together (Elk Valley, Robson Valley, Seaton Creek, Trail area, etc.). In our view, an analysis based on BEC units, for understanding the issues that face hardwoods, is of limited value. We have therefore defined five forest types based on the proportion of hardwoods within a stand. These are:

- **Cottonwood dominated stands (> 80%).**
- **Aspen dominated (> 80%) stands.**
- **Birch dominated (>80%) stands.**
- **Hardwoods as a component (21-80%) of mixed conifer/hardwood stands.**
- **Hardwoods as a minor component (1-20%) of conifer stands.**

There are two other minor stand types that are a result of unique disturbance factors. These are:

- **Hardwoods in small stands in avalanche paths, steep ravines and talus slopes, as a result of disturbance created by snow, rock and soil movements.**
- **Hardwoods in small stands as a result on construction activities that result in exposed soils.**

Each of these is discussed below.

Pure Cottonwood stands (>80%): All stands that contain > 80% cottonwood are located in riparian floodplain areas, mostly along the major rivers. Smaller stands occur on alluvial portions of several secondary rivers. Cottonwood distribution and recruitment in these areas is driven primarily by fluvial process, with logging and fire as lesser sources of disturbance. Management of these stands is defined by the provincial riparian guidelines for crown land. The presence of private land is also a major factor defining management options for these stands.

Pure Aspen (>80%) stands: Large aspen dominated stands occur on a range on sites across the Basin. Many of these stands occur on south-facing slopes in the Rockies, presumably as a result of fire disturbance. The largest stands are in the Robson Valley and in the Trail area. At Golden there are large stands on south-facing slopes above the Blaeberry River and on the benches west of the Columbia River. Some pure stands and extensive mixed cottonwood and aspen stands occur in the Elk River valley. (Aspen stands also occur south of the Elk River on private lands owned or managed by TEMBEC. Data from this area were not included in the assessment). Smaller stands occur on south-facing slopes in many other areas. These sites tend to be especially fire prone and are often preferred wintering sites for ungulates. They generally lack significant cattle browsing. Given present log markets, commercial logging is unlikely to a major factor on these sites in the near future. Logging, as a tool for ecosystem restoration, may however, be a factor on such sites. (There are also some smaller pure aspen stands scattered throughout the study area. Those stands are considered here in the management regime for the mixed conifer/hardwood stands described below.

Pure Birch (>80%) stands: These stands are distributed across a range of site types and BEC units (Bull River, Flathead, Palliser, Upper Goldstream and Downie, Blaeberry, Little Slocan, Corn Creek, Goat River, Upper Duncan and Castlegar areas). Birch form close to pure stands (80%+) in only a few small areas in the Basin (Table 11). Since these stands are minor in extent, we will not consider this category in the remainder of the report. It is assumed that such sites will be considered in the management regimes for the following two categories.

Hardwoods as a component (21-80%) of mixed conifer/hardwood stands: All three hardwoods occur as a component of mixed stands throughout the Basin. Although some scattered stands occur elsewhere, most stands with a significant hardwood component are found at lower elevations in the major river valleys. Logging, silviculture practices, ungulate and cattle browsing will be significant factors on these sites.

Hardwoods as a minor component (1-20%) of conifer stands: There are extensive areas in the study area where aspen, birch and cottonwood occur as a minor component (>20%) in conifer forests. Hardwoods in this forest types are very important for wildlife, as indicated earlier. On these sites forest harvest for conifers will be the primary source of disturbance and silviculture actions the primary human action affecting hardwood presence.

Hardwoods in small stands on avalanche paths, steep ravines and talus slopes, as a result of disturbance created by snow, rock and soil movements: This is a minor component but is notable for the different source of disturbance that creates the stands. It is likely that aspen occurs where avalanches knock down aspen stands, or mixed stands, on a regular basis. Cottonwood and birch on such sites may also regenerate by sprouts but may also develop from seed in areas of exposed soil due to avalanche action or in sites created by soil movement and rock fall. These stands are found throughout the Basin but are generally too small to be identified on the 1:250,000 mapping included here. Forest management on these sites will be defined by the grizzly bear guidelines. Forest harvest will be restricted in areas adjacent to paths (J. Bergenske, pers. comm.) but this will not alter the natural processes of soil movement that create these stands. This type is of minor importance and at low risk from human activity and is not discussed further.

Hardwoods in small stands as a result on construction activities that result in exposed soils: Hardwood recruitment conditions are provided by construction activities such as road and dike construction. Small linear stands of hardwoods along roads are common throughout the study area. There are also narrow cottonwood stands on the dikes in the Creston area that likely date from the construction of those dikes in the 1920's to 1940's era. This type is limited in extent and will not be considered further.

4.6 RISKS FACED BY HARDWOOD STANDS IN THE BASIN.

We have attempted below to identify the long-term risks faced by hardwoods in the Basin. The first section lists the critical assumptions used in our assessment, followed by a discussion of the conservation value of different stand types, the overall degree of risk faced by these stand types and the specific risks they face in the Basin.

4.6.1 ASSUMPTIONS

As a result of this literature and data review, we have made several assumptions concerning potential management actions and factors affecting the future of hardwoods. They provide the context for our assessment of risks.

Harvest aimed at using hardwoods as a major wood source in unlikely to be a major factor in this area in the near future. Although hardwoods may be harvested where they occur in conifer stands, it is unlikely that pure aspen stands, especially on steep slopes, will be considered for harvest in the near future. Cottonwood stands on Crown land in riparian areas are unlikely to be harvested in the near future since they are a low value wood but have high wildlife values. At least two forest districts (Cranbrook and Invermere) have removed cottonwood dominated stands from their AAC calculation. There is more demand for birch but birch logs are generally taken as part of salvage during conifer harvest.

Wildfire is unlikely to be a significant factor in the future of hardwood stands, even with climate warming impacts. We have little expectation that the policy of tight control of wildfire will change in the near future, either on forestlands or in protected areas.

The harvest of conifers will be the major source of disturbance in forests in the Basin in the foreseeable future in the lower elevation areas where most hardwoods occur.

Harvest and silvicultural strategies aimed at optimizing conifer survival will be a dominant factor affecting the survival of hardwood species in mixed stands, in the long term. Hardwood management will have to fit into a regime of intensive forest management for conifer fibre production over much of the study area. As indicated earlier, hardwoods provide a very important source of potential cavity sites in these forests.

National and provincial parks cannot be expected to provide extensive areas of hardwoods in the long term. Most parks in the Basin are at higher elevations where fewer hardwood stands are found. Fire policy over the last 100 years in protected areas has had a severe impact on hardwoods in these areas. Masters (1990) indicates that the fire cycle in Kootenay National Park from 1928-1988 was in excess of 2700 years, compared to the interval of 130 years for 1788-1928 and 60 years from 1508-1778. Attempts at controlled burns to re-create a more natural seral sequence have been small in area in the parks in the Basin, although larger burns have been carried out in Banff National Park. The best sites for burns that would shift to aspen stands occur along major valleys in the parks that are generally the routes used by major highways. Concerns over scenic values may limit options for initiating large-scale burns.

Cattle and ungulate browsing is likely a major determinant of hardwood survival in the drier portions of the Basin. This issue is very important in the Rocky Mountain Trench, Elk Valley, Robson Valley and other areas with substantial cattle and ungulate populations.

Controlled burns and slashing may be used to re-initiate aspen stands and create early seral conditions for ungulates in some areas, primarily on south-facing slopes in the Rockies and in the Trench. Several projects of this sort, carried out or funded by the CBFWCP, are affecting hardwoods. However, we consider the total hectares and overall impact as minor compared to the other issues affecting hardwoods.

The flooding of large areas along the major rivers in the study area by hydroelectric dams, settlement and dike construction for agriculture has had a major impact on the distribution, abundance and health of riparian cottonwood stands in the study area.

Private land logging, farming and grazing will be a major determinant of ecosystem health in floodplain areas of the mainstem rivers in the immediate future. A large proportion of riparian areas on major rivers are found on private land in the Basin.

4.6.2 PRESENT STATUS, CONSERVATION VALUES AND DEGREE OF RISK BY STAND TYPE

Below we have made an assessment of the conservation value of the hardwood stands identified in Section 4.5. A description of their conservation value is followed by an assessment of the risks faced by each type in the Pacific Northwest to provide some context for our assessment. We then considered the more specific risks occurring in the Basin. Each of these stand types result from different sources of disturbance (logging vs fluvial disturbance) and must be managed within the context of a different mix of management issues.

4.6.2.1 Pure Cottonwood stands (> 80%).

Conservation value: Cottonwood stands in floodplain riparian areas provide very high values for a wide range of mammals, nesting songbirds, and riverine bird species. Many authors consider this habitat type one of the most important in western North America.

Historic Impacts: Cottonwood stands are a sub-set of floodplain riparian habitat complexes that are very important for both wildlife and fish. Pre-settlement there were major riparian complexes in the Kootenay drainage from Canal Flats to Rexford, Montana and from just above Bonner's Ferry, Idaho to the outlet of the river into Kootenay Lake. Other important floodplain areas were located on the Moyie River, Elk River, the St. Mary's River, the Lardeau and lower Duncan rivers. In the Columbia system, these habitat complexes occurred from Canal Flats to Golden on the Upper Columbia, in the Boat Encampment area and from Revelstoke to the Upper Arrow Lake. There were also extensive stands between the former Arrow Lakes, along the Slocan River and on portions of the Salmo River.

All of these areas except the upper Columbia wetlands have been severely compromised in both function and extent since white settlement. The Libby, Duncan, Mica and Arrow Reservoirs have inundated large areas of these habitat types. Probably the largest and most productive of these systems, from Bonner's Ferry to Kootenay Lake, has been almost entirely replaced by intensive agriculture. Settlement in the Fernie, Creston, Bonner's Ferry, Revelstoke and Trail/Castlegar areas has also been a factor. This mix of impacts has severely compromised or has inundated over half of the linear length of the originally free-flowing portions of the mainstem Kootenay and Columbia Rivers. A small portion of the main stem river length is now flow regulated (below dams) with subsequent impacts on riparian processes. Similar riparian areas on secondary rivers (Elk, Moyie, Salmo, Slocan, Duncan and Lardeau) have been compromised by grazing, logging, and other human activity. The Upper Fraser River system in the Robson Valley continues to have a normal unregulated hydrograph and active fluvial processes although the floodplain there is compromised by land clearing and other private land activities. In total, large river riparian ecosystems are now severely restricted in extent within the CBFWCP area.

Degree of risk across the Pacific Northwest: The kinds of riparian cottonwood stands that occur in the Canadian portion of the Basin share attributes with stands to the south in the United States' portion of the Basin, and other attributes with riparian stands in northern British Columbia and the boreal region of northern Canada. Riparian cottonwood stands are considered to be at high risk in the Pacific Northwest by several authors. Others indicate that such systems along prairie rivers on the Great Plains and southwest region of the United States are also at risk. Cottonwood stands are limited in riparian situations in these areas and dams and other human activities have had a major impact on these limited stands. On the other hand, cottonwood stands are very common along many northern rivers in British Columbia (tributaries of the Peace, Stikine, Taku, and Liard rivers) and in other parts of the province (tributaries of the upper Fraser River system, and coastal drainages such as the Bella Cola and Heathrow rivers). Human impacts have been lower in these areas in general and extensive hardwood stands still exist.

Sources of risk within the study area: These stands are of exceptional importance to both fish and wildlife species, however, they make up <2% of forest stands in the study area. This would argue for giving these stands a high priority in terms of future actions. The major risks faced by these stands in the study area include:

- **The replacement of riparian cottonwood stands over time, by conifers, as the seral sequence progresses.** A combination of wildfire and fluvial process has maintained these stands over the last 100 years. Without fire or harvest, these stands may be replaced by spruce and cedar-hemlock stands, depending on the degree of disturbance provided by fluvial processes.
- **The impact of cattle and ungulate browsing is a significant risk in riparian areas in the Elk Valley, Rocky Mountain Trench, Robson Valley and Creston areas.**
- **The loss of stands due to land clearing on private land.** This does not appear to be a major problem. Work being completed on the Kootenay River indicates that land clearing for agriculture has stabilized along that part of the river (Jamieson and Braatne 2001).
- **The loss of older age stands on private land due to logging.** This would appear to be an issue in the West Kootenay and perhaps in the Robson Valley. It does not appear to be a major problem in the Invermere, Golden and Cranbrook Forest Districts (T. Volkers, D. Monchak, pers. comm.).
- **The loss of stands due to sub-division and settlement.** Some impacts are occurring in settlement areas, as around the town of Fernie and in some areas in the West Kootenay. The Agricultural Land Reserve has limited development along the Upper Kootenay and Columbia rivers to date, however, the continued expansion of the tourism sector in the Fernie, Invermere, Kimberley, Cranbrook and Golden areas is creating more pressure for development along rivers.
- **The expansion of hybridized plains cottonwood and black cottonwood on the Kootenay River.** Plains cottonwood was introduced early in the century in the Bonner's Ferry area and has expanded downstream, as hybrids, as far as Kootenay Lake (Jamieson and Braatne 2001). The potential impacts of this issue on wildlife are not known but are not expected to be severe since plains cottonwood and black cottonwood have similar ecologically attributes.

4.6.2.2 Pure Aspen (> 80%) stands.

Conservation value: These stands are important songbird nesting areas and occupy sites that in early seral stage are important ungulate wintering areas. They may also be important as sites for neo-tropical migrants.

Historic Impacts: Unlike the cottonwood stands described above, this type has seen minimal impact from human activities in the past and may in fact be more common now than it was historically, as a result of human caused fire.

Degree of risk across the Pacific Northwest: Some authors suggest that aspen stands are declining across western United States due to lack of fire (Cartwright and Burns 1994, quoted in Kay 1997a) and also from browsing damage. Aspen stands in the Alberta foothills and boreal edge have in fact expanded substantially since white contact (B. Church, pers. comm.). Hessburg and Smith (1999) suggest a minor increase in cottonwood and aspen stands in the United States portion of the Columbia Basin, although this may be an artifact of younger stands created by disturbance in the early part of the century maturing to where they were picked up in their mapping in a later era. Aspen stands in both northern Alberta and northeast British Columbia are now subject to extensive harvest activity. Kay (1997a) and others indicate that aspen stands in the mountain national parks are in severe decline due to replacement by conifers and browsing by elk.

Degree of risk within the Basin: These stands occur in most of the major valleys in the Rocky Mountains. They are extensive in the Robson valley (8319 ha) and in the Golden area (6374 ha).

Specific risks faced by these stands are:

- **Conifer ingrowth in aspen stands as a result of lack of fire.** Without fire or other disturbance, these stands may eventually be replaced by conifers or shift to mixed stands.
- **Controlled burns or slashing aimed at improving ungulate winter range.** The impacts of controlled burns and slashing carried out by the CBFWCP and other wildlife interests are presently a minor impact on a regional scale. This may not be the case for aspen stands on south-facing slopes in the Rockies in the long-term. In the Muskwa and Tuchodi valleys in the northern Rockies, most south-facing slopes have been returned to a mix of grasses and early seral aspen stands because they are burned regularly for wildlife interests to maintain them in that condition for ungulates.
- **Cattle grazing.** Grazing by cattle on the steeper slopes where most pure aspen stands occur is uncommon. It may be an issue in stands at the toe of such slopes, or in valley bottom areas.
- **Potential conversion to conifer production.** There are 4043 ha of aspen dominated stands in the Arrow Lakes Forest District (Table 11). Conversion of these stands to conifers is being considered as an option in planning for that area.

4.6.2.3 Hardwoods as a component of mixed (21-80%) conifer-hardwood stands.

Conservation value: These stands are important songbird nesting areas and occupy some sites that, in early seral condition, are important ungulate wintering areas.

Historic Impacts: Although these stands are, as above, partially the result of early human activity and fire, they have been impacted by other human activities to a much greater extent than the type described above. Logging, land clearing and settlement have all had an impact.

Degree of risk across the Pacific Northwest: Hardwood stands on better sites have seen more human impact that similar stands on steep slopes, as described above. Grazing, farming, logging and settlement all occur in such areas in the American portion of the Columbia Basin. Impacts in other parts of British Columbia have been less severe, given the extent of such stands in many areas. Harvest however, is a major impact in the northeast part of the province, especially in relation to older age stands. The "unmixing" of stands is also a concern where silviculture and harvest practises may lead to pure hardwood or pure conifer stands.

Degree of risk within the Basin: These stands occur in most of the major valleys in the Rocky Mountains, but are most important in the Robson Valley, the Golden area, parts of the Trench, and in the Elk Valley. Many stands are on private land. They cover some 184,477 ha. (3.9% of the study area). The major risks faced by these stands in the CBFWCP area are:

- **Stand conversion to increase conifer timber production.** In some areas, such sites are being considered for conversion to conifers to increase site production, as described earlier.
- **Conifer ingrowth in aspen stands as a result of lack of fire.** On such sites both better site condition and lower risk from fire have resulted in generally older stands with a significant conifer component in many areas.
- **Browsing by cattle and wild ungulates.**
- **Declines as a result of forest ingrowth and lack of fire in the Rocky Mountain Trench:** Several studies have documented the loss of grasslands to forest ingrowth in the Rocky Mountain Trench however there has been minimal work done on the impact of lack of fire on aspen stands in the Trench.
- **Logging and controlled burns aimed at improving winter range for cattle and ungulates.** Trench restoration program activities are a significant factor on some site types in the Trench.
- **Aspen cutting to stimulate suckering for wildlife forage.** This approach has been used in a few areas in the Trench as an emergency source of browse for elk during a severe winter (C. Purdy, pers. comm.) and on two sites in the Elk Valley (D. Phelps, pers. comm.). Under severe grazing pressure, aspen stands can be eliminated by such action.

4.6.2.4 Hardwoods as a minor component (1-20%) of conifer stands.

Conservation value: Where hardwoods occur within conifer stands they contribute biodiversity values far out of proportion to their percent occurrence with the stand (see Section 4.2.6).

Historic Impacts: There are no data on the extent of conifer forests with a hardwood component in the past. It is likely that fire maintained a hardwood component in most forests, as did gap dynamics.

Degree of risk across the Pacific Northwest: The maintenance of hardwoods as a component of conifer stands is a major issue identified by Bunnell et al. (1999) that applies across the Pacific Northwest. A hardwood component is common in most forests across British Columbia.

Degree of risk within the Basin: Stands with a minor hardwoods component are well distributed across the study area and cover some 280,058 ha (5.8% of forested land base of the study area). The major factor affecting hardwoods in these stands will be logging-initiated disturbance. Hardwoods recruitment is occurring following logging in these stands, often at very high densities. The critical question in the long term however, is whether or not the process of logging, followed by silvicultural actions, will allow for the maintenance of hardwood presence over a series of short-term (90 year) rotations. Bunnell et al. (1999) cited studies from northern Europe that identify the decline in downed wood from 30-40% in unharvested forests, to 10-20% after one rotation and 1% after several rotations. It is important to ensure that similar figures do not apply to hardwoods in the future. We emphasize that we found no definitive work to suggest that present forest management strategies will have a negative impact on the hardwood component in conifer forests. We have identified this issue as a potential risk to draw attention to the need to consider the very long-term implications of present silviculture strategies.

In protected areas, under present management regimes, a totally different problem, i.e. the as almost total lack of disturbance, may, over the long-term, result in a decline in the hardwood component in conifer stands.

4.6.3 RISK ASSESSMENT

Based on the assessment above, we first made a qualitative judgement of each of the risks faced by each ecological stand type within the study area and summed the risk rating for several factors (Table 13). Our risk assessment was based on the following:

4 = very high risk
3 = high risk
2 = medium risk
1 = low risk
0 = no risk

This gave us an estimate of the risk faced by each stand type in the study area. We then created a risk factor (last line) based on a comparison of the sums for each stand type where:

1 = 1-8
2 = 8-16
3 =17-24
4 =26-32.

This risk assessment for each stand was then transferred to column 4 in the next table.

Table 14 compares the conservation value, historic losses, regional status and local risk factors for the four stand types described in Section 4.7.2. An overall risk rating was developed by summing the values in the first four columns.

Table 13. Initial risk ratings for various impacts on four different hardwood stand types. (Based on the professional opinion of the authors only).

Potential impact	Cottonwood dominated stands (80%+)	Aspen dominated stands (80%+)	Hardwoods in mixed stands (20-80%)	Hardwoods as a minor component of conifer stands (1-20%)
Crown Land Issues				
Hardwood harvest	1	1	3	2
Conifer harvest	1	2	4	4
Silvicultural practises	1	1	3	4
Firewood cutting	0	1	1	1
Fire management policies-protected areas	1	1	1	4
Fire management policies-forest lands	1	3	3	3
Flow regulation below dams*	3	0	0	0
Ungulate browsing	2	4	3	1
Cattle browsing	2	1	4	2
Sub-total-Crown land Issues	12	14	22	21
Private Land Issues				
Settlement	2	1	1	1
Clearing for farmland	1	1	1	1
Private timber harvest	3	1	3	3
Cattle browsing on private land	3	1	3	1
Flow regulation below dams	4	0	0	0
Sub-Total – Private Land Issues	13	4	8	6
TOTAL	**25**	**18**	**30**	**27**
Ranking[1.]	4	3	4	4

* Although this is an important concern, there is little crown land in the river reaches affected except within the river channel itself. (Revelstoke reach, Castlegar to Waneta, Duncan dam to Kootenay Lake).

The sub-totals for crown and private land issues indicate that private land concerns are a major concern for cottonwood stands but are less so for other stand types. Conversely, management actions such as fire control and forest harvest are major concerns for mixed stands and stands with a minor hardwood component, but are less important for cottonwood and aspen dominated stands.

Table 14. An overall risk rating for four hardwood stand types in the CBFWCP area. (Based on the professional opinion of the authors only).

Stand type	Importance of ecological type to fish & wildlife[1.]	Historic Losses[2.]	Risk in Pacific North-west[3.]	Risk in the study area[4.]	Overall Risk Rating[5.]
Cottonwood dominated stands (>80%)	4	4	4	4	**16**
Aspen dominated stands (>80%)	3	1	1	3	**8**
Hardwoods in mixed stands (20-80%)	3	2	2	4	**11**
Hardwoods as a minor component in conifer forests (1-20%)	4	2	3	4	**13**

1. Based on arguments made in this report.
2. Based on the arguments provided above.
3. Based on the arguments provided above.
4. Based on discussion in Section 4.7.2 and Table 7.
5. A sum of the four factors to the left.

This suggests the following descending order of priorities in terms of stand types.

1. **Cottonwood stands, in floodplain riparian areas along the major rivers.**
2. **Hardwoods as a minor component in conifer forests.**
3. **Hardwoods in mixed conifer/hardwood stands.**
4. **Aspen dominated stands.**

5.0 CONCLUSIONS

Our conclusions, based on the assessment provided above are that:

- **The conservation of the remaining floodplain riparian areas in the Basin should be considered a priority for the CBFWCP.** Cottonwood stands are part of a complex of habitats found in riparian areas and especially alluvial floodplain areas. A host of projects in the USA and Europe have concluded that these areas are of exceptional importance in terms of ecological process and fish and wildlife values. B.C. Hydro dams have had a major impact on these areas. Therefore, actions in these areas would relate directly to the restoration objectives of the Program. While there are several other funding agencies that support restoration actions in other areas (Forest Renewal BC, Rocky Mountain Elk Foundation), there is less direct support for work in riparian areas. Finally, work in riparian areas fits the mandate of the program to support habitat restoration for both fish and wildlife species.

- **Retaining hardwoods as a minor component (1-20%) in the coniferous forests of the study area requires the consideration of researchers and managers throughout the study area.** While logging will provide the disturbance necessary to the long term viability of the hardwood component in conifer stands across the Basin, silvicultural strategies aimed at optimizing conifer survival may, over several rotations, have unforeseen impacts on hardwoods. Working with all the various interests concerned to look at this issue should be considered a priority. A sub-set of this problem is found in the Trench and other major valleys where hardwoods need to be considered in the context of conifer ingrowth, logging and grazing by both wild ungulates and cattle.

- **Mixed wood stands (21-80%) in some areas are subject to pressure for conversion to conifer stands.** This issue is being considered primarily in the Arrow Lakes Forest District. The CBFWCP should work with the various interests there to develop a strategy that maintains the critical role of hardwoods in such forests.

- **The management of aspen dominated stands on south-facing slopes should be addressed in order to provide for a mix of ungulate and avian values.** Absent a change in the economics of aspen harvesting, little logging is likely to occur on these sites. Prescribed fire, slashing and logging initiated for conservation rather than economic purposes will likely be the major tool available for creating a more complex age class structure on such sites. As a result, management prerogative will lie to a large degree with MELP and MOF, with lesser involvement from the major forest companies. Managing these sites to balance ungulate and songbird requirements will be an important challenge to wildlife managers. (Aspen dominated stands also occur in some areas on lower gradient sites where they are subject to pressure for conversion to conifer stands. These stands should be considered in the context of the same issue related to mixed wood stands).

6.0 RECOMMENDATIONS

Based on the conclusions above and the previous sections of this report, we suggest the following as potential strategies and actions for the CBFWCP. A listing by priority and project cost estimates are provided at the end of this section.

6.1 FURTHER REGIONAL ANALYSIS

We suggest the following actions to expand our understanding of hardwood issues at a regional level.

- ❑ **FURTHER ANALYSIS OF HARDWOOD AGE CLASS STRUCTURE**

The analysis of age class data by forest district completed here suggests that hardwood recruitment may be occurring differently in different biogeoclimatic zones. The forest cover age class data should be analyzed by BGC zone to clarify the reasons for the age class structures found in the analysis by forest district. Analysis by site series could be attempted but may be of limited value due to limitations in sample size. Slope and aspect could also be assessed, especially in relation to aspen stands. This data should also be assessed based on Natural Disturbance Types (See Table 6.2.1. in App. I.). This may clarify the levels of recruitment and age class structure of stands that are occurring under different disturbance regimes. We would suggest that this analysis would be most effective if the floodplain areas of the major rivers were removed from the analysis and assessed separately. Hardwood and especially cottonwood ecology on floodplains is based on a unique disturbance regime. Hardwood age class distributions should be developed for the major floodplains areas to see if hardwoods in these areas have an age class structure that is distinct from nearby upland stands. At present we do not know if the younger age class stands of cottonwood indicated in Figures 7 and 8 are occurring in riparian or upland stands. The best study site options are:

- The Kootenay River floodplain in the Trench (LUs C32, C30 and C33)
- The Fraser River floodplain of the Robson Valley [LUs RB 5, 18 and 21)
- The Elk River floodplain of the Elk River valley (LU C24).

The boundaries of the floodplain on the Elk River is available in GIS form from prior work (Jamieson and Allen 1997) and from floodplain identification projects carried out by the Water Resources Branch. Ongoing work on the Kootenay River indicates that recruitment created by fluvial processes is not picked up in the forest cover database, but this may not be the case in other areas, especially on larger rivers such as the Fraser River.

- **SPONSOR A REGIONAL WORKSHOP ON HARDWOOD ECOLOGY.**

We suggest that the CBFWCP organize a workshop, with partners, to raise the profile of hardwoods in the Basin and to stimulate thinking in the resource management community around the issues raised here. This workshop would be most effective if it were carried out following the completion of three analyses recommended above. This should be a cooperative project with the B.C. Ministry of Forests, B.C. Ministry of Environment, Lands and Parks, the major forest companies, national and provincial parks, and wildlife interests to:

- Raise the profile of the issue;
- Review how hardwoods are being managed across the Basin in harvesting, silviculture and restoration plans;
- Assess the assumptions and conclusions in this paper;
- Develop, for everyone involved, a clearer understanding of long-term options for maintaining hardwoods in both riparian areas and upland forests;
- Find agreement on research and management priorities for hardwoods.

We suggest a two-stage process. A first step would be to send this paper and the accompanying maps to any regional wildlife and habitat biologists, forest ecosystem specialists, forest planners and company foresters across the Basin who have expressed an interest in this subject. Based on this, a one day or half day meeting of 5-15 people could be held to develop an agenda for a workshop. This would set the stage for a larger workshop to bring together research and management interests from across the Basin to consider hardwood management issues.

6.2 PROJECTS RELATED TO COTTONWOOD DOMINATED STANDS (>80%)

We would suggest the following projects related to this stand type.

- **Document the historic status and losses of mainstem riparian habitats in the Basin.**

Estimates of the hectares of riparian habitat inundated by the United States' portion of the Koocanusa Reservoir are available (Yde and Olsen 1984), as are estimates for many of the other major reservoirs on the United States side of the Basin. They are used as a benchmark for measuring the restoration activities of Bonneville Power Administration (BPA). No data on riparian areas are available for the Canadian reservoirs in the system, although there are data on pre-flooding winter range values for some reservoirs. This information is important for understanding the pre-settlement and pre-flooding status of riparian areas in the Basin. Historic air photos are available for most of the impoundment areas. There are now tools available to allow a comprehensive assessment of riparian habitat types based on a range of recent studies in the USA. Work in the BPA project on the Kootenay River indicates that it is possible to map riparian habitats from historic air photos (Jamieson and Braatne 2001).

- **Identify acquisition options on the floodplains of major rivers.**

An assessment of acquisition options in the riparian zone of the Elk River has been completed (Jamieson and Allen 1997) where individual stands and properties were identified and assessed. Acquisition options in the Columbia wetlands are identified in Jamieson and Hennan (1998) and along the Goat River in Jamieson and Herbison 1997. A similar assessment has been done along the Fraser River in the Robson Valley (Norecol Environmental Consultants Ltd. 1992). Similar assessments should be completed for the Kootenay River from Skookumchuck to Wardner, the St. Mary's River, Moyie River, Salmo River, Slocan River and other remaining major river floodplain areas where there is substantial private land ownership. This would provide a region-wide assessment of options for acquisition and the use of conservation easements in these areas.

- **Pursue acquisition and conservation easements in riparian areas.**

Due to the importance of riparian stands and the predominance of private land along major rivers, the CBFWCP should pursue options for acquisition prior to the completion of the surveys suggested above, especially in the Lardeau River, Upper Fraser and Kootenay River areas. Many of these areas are quickly being priced out of reach for acquisition but conservation easements may be an important option. A project could be considered that completed a survey of a reach, as above, and was then followed by a program aimed at acquiring conservation easements in that reach.

- **Identify options for manipulating flows below flow-regulating dams to re-establish cottonwood recruitment.**

Fluvial disturbance processes do not occur below most flow-regulating dams and cottonwood recruitment is nonexistent in many river reaches below dams (Polzin 1998, Johnson et al. 1976, Bradley and Smith 1986, Rood and Heinze-Milne 1989, Rood and Mahoney 1990, Rood and Bradley 1993, Snyder and Miller 1991, Stromberg and Patten 1992, Johnson 1992, and Rood et al. 1995). Tools have been developed on the Oldman River, Truckee River and other western rivers to demonstrate that cottonwood recruitment can be initiated by occasional spring releases during high flow years (Rood and Gourley 1996, Rood et al. 1998). These practices are now widely accepted and promoted by resource managers in Alberta (Mahoney 1997) and Nevada (Rood and Gourley 1996).

Most river reaches where this option might be applied on the mainstem rivers of the Basin have been flooded by present dams or are compromised by agricultural and settlement activities. However, this approach could be applied to relatively short river reaches below the Mica, Revelstoke, Keenleyside and Duncan dams. The CBFWCP should consider a project, working with B.C. Hydro and the Water Use Planning process to manipulate flows on an experimental basis below one or more of the dams mentioned above. Spring flows that allow for cottonwood recruitment are only required every 10-20 years to maintain a range of stand ages. Therefore, releases in high flow years can be used for this purpose at low cost. Fish requirements may also require flow manipulations to mimic spring flood events, as is being attempted at Libby dam for white sturgeon. The incremental cost of designing these releases such that they benefit cottonwood are low.

Potential study sites include the Duncan-Lardeau Flats where there is a complicating factor since the hydrograph in the floodplain portion of the river is a result of the combined flows of the Duncan River (regulated) and the Lardeau River (unregulated). Such a project in the Revelstoke area would provide good profile for this technique, but over a relatively short river reach. The Columbia River reach below the Keenleyside Dam in the Castlegar area supports few cottonwood stands and is affected by flow released by dams on both the Columbia and the Kootenay River. The reach below Mica dam is very short. Flows are being altered at Libby dam for sturgeon and may in the future be designed to provide for cottonwood recruitment. This may provide some long-term options for re-establishing cottonwood recruitment in the Creston area. The CBFWCP could co-fund or otherwise support this work as it evolves, if benefits can be demonstrated for the Canadian side of this river reach. The first stage in this process would be to carry out inventories in two or three of these areas to see if any cottonwood recruitment is occurring with the present regulated hydrograph. Vegetation sampling strategies are well developed for this kind of work (see Jamieson and Braatne 2001).

- **Contribute to future work to develop a better understanding of ecological processes in alluvial floodplain areas.**

Alluvial floodplain reaches of major rivers are of critical importance for fish and wildlife. The Upper Columbia reach from Invermere to Donald and the Upper Kootenay from Canal Flats to Wardner are among the largest remaining alluvial reaches in the entire Columbia Basin (Stanford 1995). Ecological process in such areas is a major area of research and management interest in the USA. Geomorphic and ecological processes in such reaches are major determinants of both fisheries values (spawning gravels, pool establishment) and wildlife values. The CBFWCP should consider participating in future work in these systems. The Kootenai Tribe at Bonner's Ferry has recently received funding for a major project looking at returning ecological process to the highly modified Bonner's Ferry to Kootenay Lake reach of the Kootenai River, to benefit white sturgeon and a range of other species. Work on the Canadian side in this reach should be encouraged. Research should also be encouraged in the essentially unmodified alluvial reaches in the Upper Kootenay (Canal Flats to Wardner) and Upper Columbia wetlands. Work in such unmodified systems can provide important guidance in the restoration of ecological function in heavily altered systems (See Braatne et al. 2001).

- **Assist in developing practical tools for managing grazing to maintain cottonwood recruitment.**

Research and field trials to document the options for maintaining natural recruitment processes in riparian areas where cattle are present should be considered. Work is underway on this issue in Alberta with the "Cows and Fish" group, in central B.C. through an agreement between DFO and the B.C. Cattleman's Association, and in several areas in western United States. Potential tools such as fall grazing, permanent fencing and temporary electric fencing (to allow a 3 to 10 year rest period that will allow recruitment cohorts to grow out of reach of cattle) could be tested. The CBFWCP could participate in demonstration projects and further research on this issue on sites in the Trench, the Creston area, the Robson Valley and the Elk River valley.

- **Document songbird use of riparian areas during migration in a comparative study with upland hardwood sites.**

It is important to know if the attributes required by neo-tropical migrants during stopovers are provided only by riparian areas, or also by upland hardwoods stands (see Section 4.2.4). Further, if songbird stopover sites are restricted to riparian areas, it is important to know if their use of such areas is solely or primarily in the hardwood component within such areas. This work should be based on the techniques described in Pojar (1995) and other similar community-wide studies, to separate out the various factors operating in these stands. The study should be at least 7 years in duration to document the effects of annual floods and shifts in migration patterns between years. This work could be carried out in tandem with the breeding bird survey in hardwood stands proposed below.

- **Document the range-wide status of bird species that use hardwoods and riparian areas, for nesting and during migration.**

Indices of bird abundance and diversity are relatively constant for different age classes of hardwoods. However, the species mix in each age class is very different. We found no work that looked at the degree of risk faced by species within each of these bird communities. If the species using old age class stands are at risk, but those using early seral stages are not, then this provides some very important information for managers, even if actual abundance and number of species are similar between the two types. The CBFWCP should consider a study that looks at the degree of risk faced by each species in each age class to discern if there are species or guilds using one particular age class that are of particular concern across their range.

- **Investigate options for the harvest of understory conifers in riparian cottonwood stands.**

Based on the assessment of age class structures in floodplain areas proposed above, we may find that there are some areas where the age structure is such that there will be periods in the future where few mature cottonwood stands will occur. It would be useful to look at the efficacy of tools to "fill in the gaps" in the age class structure at a landscape level. Tools that could be considered include: removal of conifer understories in old cottonwood stands to extend the life of the stand; thinning of cottonwood stands to stimulate growth in size at an earlier age; or other strategies for maintaining cottonwoods through "low spots" in the age class curve. This project would require long-term monitoring of the responses of stands treated. Potential study sites include some sites along the Elk River and areas in the Robson Valley.

- **Develop educational materials for landowners in floodplain areas.**

The CBFWCP should develop a guide to the ecology of riparian areas for private landowners that identifies the problems with recruitment and maintenance of cottonwoods and provide options for the management of riparian areas. It should also identify present government incentives to landowners to maintain riparian areas. This project could be done cooperatively with other agencies involved in riparian issues. Present guides are available but they do not document the issues around hardwood recruitment and do not deal effectively with floodplain issues or fluvial processes. The CBFWCP could also provide a service for developing long-term conservation plans for private properties in such areas. Many landowners would probably consider hardwoods and riparian values in their operations but lack the tools to do the necessary long term thinking and planning. A consultant with a wide background in the practical application of ecological tools could be retained to do plans for private landowners on a cost-sharing basis. A similar approach is being used by the Columbia Kootenay Fisheries Partnership and the Department of Fisheries and Oceans (DFO) to assist landowners who wish to establish in-stream structures for fish.

6.3 PROJECTS RELATED TO HARDWOODS AS A MINOR COMPONENT (1-20%) IN CONIFER FORESTS

We would suggest the following projects related to this stand type.

- **Look at implications of present regulations and management strategies on long term hardwood presence in conifer stands.**

The potential impact of silvicultural practices on hardwoods in the long term is a concern identified in this review. However, there is a wealth of research and practical experience in this area that needs to be tapped before specific projects are identified. Potential projects in this area should be an outgrowth of the proposed workshop if this subject is confirmed as a management concern by the workshop participants.

6.4 PROJECTS RELATED TO HARDWOODS IN MIXED (21-80%) CONIFER/HARDWOOD STANDS

As above, projects in this area should await the results of the proposed workshop. We suggest two areas that should be given early consideration.

- **Work with the Arrow Forest District and the IFPA process to identify options for maintaining hardwoods in the Arrow Forest District.**

The potential conversion of mixed stands and hardwood dominated stands to more economically productive conifer stands is a significant management issue in Arrow Lakes Forest District. The CBFWCP should support work in this area that will assist in resolving this issue.

- **Consider options for maintaining hardwoods in Trench restoration projects.**

Hardwoods are a component of many stands in the Trench and occur as pure aspen or aspen-dominated stands in some areas. The CBFWCP should work with the Trench Restoration Committee to find effective ways of including hardwoods in the mix of objectives for restoration work that is being done in the Trench. There are indications that wildfires, such as in the Findlay benches and Lake Enid areas, result in a major hardwood response in the dry conditions found in the Trench. The response to logging, especially with subsequent browsing by cattle and ungulates, is less clear. Data are needed on how restoration actions such as logging and prescribed burns are affecting hardwoods in the long term. One approach to developing a better understanding of these issues would be to develop a management plan for a landscape unit or set of range units that considers hardwood issues as part of the mix of issues that have to be addressed in the Trench. Potential study sites with a significant hardwood presence include the St. Mary's Prairie area, the Findlay-Dutch Creek benches, the Wilmer area, and the Steamboat benches. Other potential study sites where hardwoods are a significant component of stands can be identified from the maps provided in Appendix III. Data from the project proposed above to develop age class distributions by natural disturbance type may be useful in this assessment.

- **Investigate options for the harvest of understory or co-dominant conifers in aspen stands.**

Future work may indicate that there are gaps in the age class structure of aspen stands due to restricted recruitment as some point in time. It may then be useful to look at ways to "fill in the gaps" by the removal of conifer understories in aspen stands; harvest removal of conifers in the co-dominant stage; harvest of conifers in older stands, with slashing of aspen to stimulate suckering; or other strategies to maintain aspen through "low spots" in the age class curve. This project would require long term monitoring of the response of stands treated. Potential study sites occur in the Elk Valley, Robson Valley, Salmo River, Arrow Lakes area and the Golden area.

- **A breeding bird survey in hardwood stands.**

There is little data documenting the use of hardwood stands by birds in the study area. Work in this area would compliment work in northern B.C (Pojar 1995), in Alberta (Westworth and Telfer 1993, Schieck and Nietfield 1995) and in the USA. This work could build on the previous bird inventory work in the Robson Valley and Upper Columbia (Leong and Simpson 1993, 1994, Ferguson 1998) and should be designed in a manner similar to that of Pojar 1995. This work would clarify the requirements of birds that use hardwoods in this area and would provide guidance to managers working in these systems.

6.5 PROJECTS RELATED TO ASPEN DOMINATED STANDS (>80%).

Again, specific projects should await the discussions at the proposed workshop. However, we suggest the following project, the results of which would contribute to our understanding of the issues involved in working with these kinds of stands.

- **The development of a management plan for aspen stands on steep slopes that considers the range of values on such sites.**

Hardwood stands on steep south-facing slopes provide a range of values for wildlife. Visual characteristics are another important consideration. There are three general options on these sites.

1. Maintain these slopes in early seral condition to provide forage for ungulates using a regular burning program that operates on a 10-30 year cycle. This option is being used in many areas in the Northern Rockies.
2. Maintain these slopes in a late seral condition to provide for songbirds and cavity nesters, using a burning or logging program that operates on a 70-120 year cycle.
3. Bring these sites into the operational forestland base by allowing conifer ingrowth to develop in these stands and eventually overtop the hardwood component. The sites would then be harvested and actively managed to minimize hardwood regeneration in future rotations.

A landscape level planning process that considers these issues should be developed. The goal would be to develop a better understanding of the ecological processes that occur on these sites, given various kinds of disturbance, and then consider how best to use the forms of disturbance that can be controlled, in the form of timber harvest, slashing or controlled burns, to maintain hardwoods and associated wildlife values, over the long-term.

The best potential study sites are:

- The slopes of the Robson Valley [LUs RB 5, 18 and 21)
- The slopes of the Elk River valley (LU C24).

Other sites that could be considered are:

- Aspen-dominated slopes in the Golden area
- The slopes above the Upper Fraser River in Mount Robson Provincial Park;
- Some slopes in the Salmo River drainage
- Some slopes along Seaton and Kaslo Creeks.

An attempt was made recently to look at the fire history of aspen stands in the Robson Valley but was abandoned due to the lack of fire-scarred trees in the area (Interior Reforestation 2000). Fire history on these sites would have to be inferred from other sources.

7.0 LITERATURE CITED

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8.0 APPENDICES (On attached CD-ROM)

I. **A REVIEW OF HARDWOOD ECOLOGY IN THE CBFWCP AREA OF SOUTHEAST BRITISH COLUMBIA**

II. **A LITERATURE REVIEW OF WILDLIFE USE OF HARDWOODS**

III. **HARDWOODS DISTRIBUTION AND AGE CLASS DATA, BASED ON FOREST COVER DATA, FOR THE CBFWCP AREA.**

IV. **MANAGERS AND RESEARCHERS CONTACTED.**

APPENDIX I

A REVIEW OF HARDWOOD ECOLOGY

IN THE CBFWCP AREA OF

SOUTHEAST BRITISH COLUMBIA

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1. INTRODUCTION

The geographic area of interest to the Columbia Basin Fish and Wildlife Compensation Program (referred to as the CBFWCP area) contains forests with substantial components of broadleaf tree species represented by aspen (*Populus tremuloides*), birch (*Betula papyrifera*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). For simplicity, these species are referred to in this report as hardwoods. In the literature they are often referred to as deciduous species. Botanically they are most accurately described as broadleaf, broad-leaved, or broadleaf deciduous species. The British Columbia Ministry of Forests has generally adopted the term broadleaf species.

This report does not distinguish between black cottonwood (*Populus balsamifera* ssp. t*richocarpa*) and balsam poplar (*Populus balsamifera* ssp. *balsamifera*), both of which probably occur in the CBFWCP area although cottonwood is the main subspecies present. Although red alder (*Alnus rubra*) does occur in northern Idaho, it is not included as one of the hardwoods of the CBFWCP area.

Aspen, birch and cottonwood have received considerable research and management attention from the following perspectives: their place in biogeoclimatic ecosystem classification; hardwoods as potential species for forest regeneration; biomass production by hardwood species and their nutrient cycling relations in pure and mixed stands; and wildlife habitat aspects of hardwoods in pure and mixed stands. However, there are various questions of interest to CBFWCP that involve poorly understood aspects of ecological processes in pure or mixed stands of hardwoods. Such questions are the focus of this review.

Some of the circumstances and processes relating to the current hardwood resource in the Canadian portion of the Columbia River Basin involve questions such as:

- What is the likely distribution and proportion of hardwoods over the long term in the region given that they are not likely to be commercially harvested in the foreseeable future, except for specialty birch products? This question is addressed in Section 10.

- Assuming a continued high priority for elimination of most wildfires and little interest in prescribed fires, except for restoration of grass-dominated ecosystems in the east Kootenay region, what is the likely influence of a fire-scarce environment on long-term abundance, distribution, and age-class structure of future hardwood stands? Fire influences on hardwood stands are reviewed in Section 6.1.1 and current age-class data are summarized in Section 4. More detailed age-class data are presented in Appendix III.

- Assuming harvest of conifers will be the main regional source of disturbance into the foreseeable future, especially in the Interior Cedar-Hemlock (ICH) Zone where the largest volumes of hardwoods occur, what is the likely influence of this key disturbance factor on abundance, distribution, and age-class structure of future hardwood stands? This question is referred to in Sections 3.2 and 6.2.2.

- With regulatory and other reasons for limiting forest harvesting in riparian and alluvial ecosystems, and with aggressive suppression of fires, will periodic flood events provide sufficient disturbance for long-term maintenance of a significant component of cottonwood in flood-prone areas? This topic is briefly reviewed in Section 6.1.3.

Given the regional circumstances implied by the assumptions and questions above, there are more specific issues and questions related to aspen, birch, and cottonwood:

- If western redcedar and valley-bottom spruce gradually gain in abundance and dominance in alluvial or riparian ecosystems, as a result of reduced disturbance from fire or harvesting, will there be a long-term need to encourage harvesting of valley-bottom conifers to sustain significant hardwood stands (mainly cottonwood but also some aspen)? What silvical characteristics of hardwoods and what ecological processes would help define harvest and non-harvest options in riparian areas? Sections 2.3, 5.1, and 6.1.3 examine some aspects of these questions.

- What are the options for maintaining pure aspen stands over the long term in locations such as the Elk Valley and Robson Valley? Aside from harvesting, and perhaps also prescribed burning in some parts of the Elk Valley, are there ways to stop or delay succession to conifers in locations where long-term maintenance of pure aspen is the goal? Sections 2.1, 3.1.1, and 6.1.1 make reference to these difficult questions.

- In circumstances or locations where there is no interest in maintaining pure hardwood stands, there may still be widespread interest in long-term presence of some hardwood component in primarily coniferous forest. How can this be accomplished in the long term? This question is of major importance in the ICH Zone, a lesser issue in the IDF Zone, and a minor issue in the ESSF and PP Zones. The key regeneration and successional characteristics of hardwood species relating to this question are outlined in Sections 2, 3, 4, and 6.2.2.

Forest ecosystems of southeastern British Columbia have been part of the focus of several major conferences over the past few years but the published proceedings of these conferences contain remarkably little information on the role of hardwood species. For example, little is said about aspen, birch, or cottonwood in: *Lodgepole Pine: the Species and Its Management,* Symposium proceedings, Spokane, Washington, and Vancouver, B.C., May 1984 (Baumgartner et al. 1985); *Ecology and Management of Larix Forests: a Look Ahead,* Proceedings of an international symposium, Whitefish, Montana, October 1992 (Schmidt and McDonald 1995); *Ecosystem Management of Forested Landscapes:*

Directions and Implementation, Proceedings of a conference held in Nelson, B. C., October 1998 (D'Eon et al. 2000).

Significant hardwood information is compiled in Vyse and DeLong (1994) and in Simard and Vyse (1994) from the symposium proceedings for *Interior Cedar-Hemlock-Western Pine Forests: Ecology and Management* (Baumgartner et al. 1994). However, no major regional symposia have been held in southeastern British Columbia or neighbouring inland regions of the United Sates on the subject of hardwood ecology and management in mixedwood stands. Aspen and cottonwood are addressed in only a minor way in the comprehensive review, *Wildlife Habitats in Managed Forests*, *the Blue Mountains of Oregon and Washington* (Thomas 1979). The workshop on silviculture of temperate and boreal broadleaf-conifer mixtures (Comeau and Thomas 1996) contained important information on ecology and management of hardwood mixtures in southern interior British Columbia (Cameron 1996; Simard 1996b). In general, the assembly of information on the ecology of hardwoods in the CBFWCP area relies on syntheses from many individual publication sources.

2. KEY REGENERATION FEATURES OF HARDWOOD SPECIES

This section relies on the latest silvical information compiled by Klinka et al. (2000) for aspen, birch, and cottonwood. That synopsis, with its accompanying CD-ROM disk and 1:2,000,000 map of biogeoclimatic zone boundaries (as of 1999), together with managers' handbooks for aspen (Peterson and Peterson 1995), birch (Peterson et al. 1997), and cottonwood (Peterson et al. 1996) provide much of the detail summarized in the following sections of this review. Other key sources of information on hardwood ecology are Krajina et al. (1982), Burns and Honkala (1990), Haeussler et al. (1990), and Niemiec et al. (1995).

2.1. Aspen

Although it is only recently that aspen has become a commercially important source of pulp and fibre, the ecology of this species has been well researched in the past 40 years – more so than with birch or cottonwood. Despite this research attention, at least two aspects of aspen regeneration remain an enigma:

- The emphasis in most research reports that virtually all of aspen's production of new stems is from vegetative formation of suckers from clonal root systems does not acknowledge that every clone began with a stem of seedling origin. Does this mean that aspen of seedling origin are more prevalent than the current literature suggests?
- If aspen regeneration from clonal root systems is so prominent, how enduring is this reproductive mechanism? Like other clonable biological material, is aspen's root system essentially immortal? Or are there genetic, biological, physical, or geographic constraints on longevity of aspen root systems?

This review does not settle these enigmas about aspen's reproductive strategies. The intent is to simply alert the reader that local site conditions, determined by geographic location, recent human or natural disturbances, and biogeoclimatic site variations, probably have profound influences on whether aspen is reproduced vegetatively by root suckers or by individual seedlings. Although these aspen-focused uncertainties are less prevalent for birch and cottonwood reproduction, they should also be considered in the renewal and sustainability plans for these species as well.

Aspen's key reproductive features can be highlighted in point form based on information previously summarized by Shepperd and Jones (1985), Perala (1990a), Shepperd and Smith (1993), Shepperd (1996), and by Peterson and Peterson (1992, 1995).

- Aspen is a disturbance-dependent early successional species that reproduces by seeds but usually re-establishes itself vegetatively. Managers generally think in terms of root sucker reproduction because this method of aspen-stand renewal has been so much emphasized. Only recently has attention been given to natural aspen seedling establishment, although there is very little documentation of seedling-origin aspen stands in British Columbia.

- Aspen seedlings are most likely to be found in freshly deposited alluvial soils or in severely burned areas that have bare mineral soil. In general, seed germination is limited by the fact that aspen seed is viable for only a few days after it is shed. Furthermore, this short viability period must coincide with a continuously moist, bare seedbed to allow root establishment of seedlings. Some of the best and most recent documentation of aspen seedling establishment is from the areas burned in the Yellowstone region in 1988 (Kay 1993; Renkin and Despain 1996b; Romme et al. 1997). The burned sites that Renkin et al. (1991) reported to have seedlings in 1991 still supported aspen seedlings in 1993, despite the potential limiting factors of ungulate browsing or trampling, disease, competition between aspen seedlings, and competition from lodgepole pine seedlings. Renkin and Despain (1996b) stressed that it remains to be seen whether post-burn aspen seedlings will continue to grow and reach seed-bearing age. The concern for future seed regeneration from these aspen seedlings may be irrelevant because there have been records of seedlings as young as one year old producing suckers (Farmer 1962).
- The main method of aspen reproduction is by suckers that develop from the extensive lateral root system located just below the soil surface. Suckering is triggered when trees are cut or burned, and is promoted by the increased soil temperatures that result from exposure of the soil surface to direct sunlight. The optimum temperature range for suckering is 20° to 30° C. Light is not required for sucker initiation but reduced light levels from vegetative competition or residual canopy can slow growth of emerging suckers and lead to sucker mortality. Amount of suckering depends on the degree of stand disturbance and the inherent ability of the trees to sucker. Stand age does not affect suckering capacity, provided the stand is not subject to breakup due to old age and decay.
- Aspen, like birch, has a decreasing ability to produce sprouts from stumps as age increases. Aspen does produce root suckers at all stand ages (Figure 2.1).
- There are some records of natural two-canopy aspen stands (see Section 4), which suggests that there are some exceptions in which aspen is capable of reproducing under an existing aspen canopy. Although not yet documented, there have been suggestions that some clones are better adapted than others to develop suckers under partial shading from an existing aspen overstory. However, clearcutting is widely emphasized as the best silvicultural system for promotion of aspen suckers.
- Regeneration capacity of aspen roots is not unlimited. Root carbohydrate reserves can be exhausted by grazing or repeated cropping of young sucker stands. There is also evidence that repeated spring burns eventually cause significant reduction in sucker production. Additional constraints on aspen sucker production are: any forest floor or microclimate condition that keeps growing season soil temperatures below 15° C in the near-surface soil horizon (7-12 cm depth) where most of aspen's sucker-producing roots are located; soil compaction; root disturbance; very wet soil; and invasion by aggressive pioneers such as alder, willow, or *Calamagrostis.* In general, harvesting impacts that result in soil compaction and increased bulk density, especially in wet soils, and damage to aspen roots can restrict sucker production.

Aspen's shallow and extensive root laterals have cord-like branch roots that extend considerable distances from the parent stem. These lateral roots are the producers of suckers, and suckering is particularly abundant when lateral roots are close to the soil surface. Aspen's sinker roots occur as frequently as every metre along the lateral roots and sinker roots may descend to a depth of 3 m (Klinka et al. 2000).

Aspen's regeneration features are influenced by its tolerances to several of the key variables summarized in Table 2.1.1 and overall silvical characteristics listed in Table 2.1.2.

TABLE 2.1.1. Aspen tolerances to several key variables, based on Klinka et al. (2000).

Tolerance to	Tolerance class*	Comments
low light	L	possibly higher in saplings that have developed from root suckers
frost	H	a major species in boreal climates
heat	M	frequent on insolated sites
water deficit	L	infrequent on dry sites
water surplus	H	tolerates flooding and a strongly fluctuating water table
nutrient (mainly N) deficiency	M	infrequent in acid, very poor soils

* L – low; M – Medium; H – High

TABLE 2.1.2. Aspen's key silvical characteristics, based on Klinka et al. (2000).

Silvical characteristic	Interpretive class	Comments
reproductive capacity	H	vegetative reproduction from root suckers and stump sprouts; minimum age for seed crop is about 10 yr
seed dissemination capacity	H	dispersed by wind and water
potential for natural regeneration in low light	L	practically nil; essentially an exposure-requiring species
potential for natural regeneration in the open	H	for vegetative reproduction, sucker regeneration is proportional to degree of cutting and burning
potential initial growth rate	H	about 30 cm in first growing season from root suckers, 50 cm/yr thereafter
response of advance regeneration to release	NA	advance regeneration does not develop in the absence of adequate light
self-pruning capacity in dense stands	H	probably the highest among BC's hardwoods
crown spatial requirements	M	probably the narrowest among BC's hardwoods
light conditions beneath closed-canopy, mature stands	H	associated with well-developed understory vegetation
potential productivity	H	site index (50 yr @ breast height) close to 35 m on most productive sites
longevity	L	<200 yr; recorded maximum is 228 yr; pathological rotations are between 50-120 yr

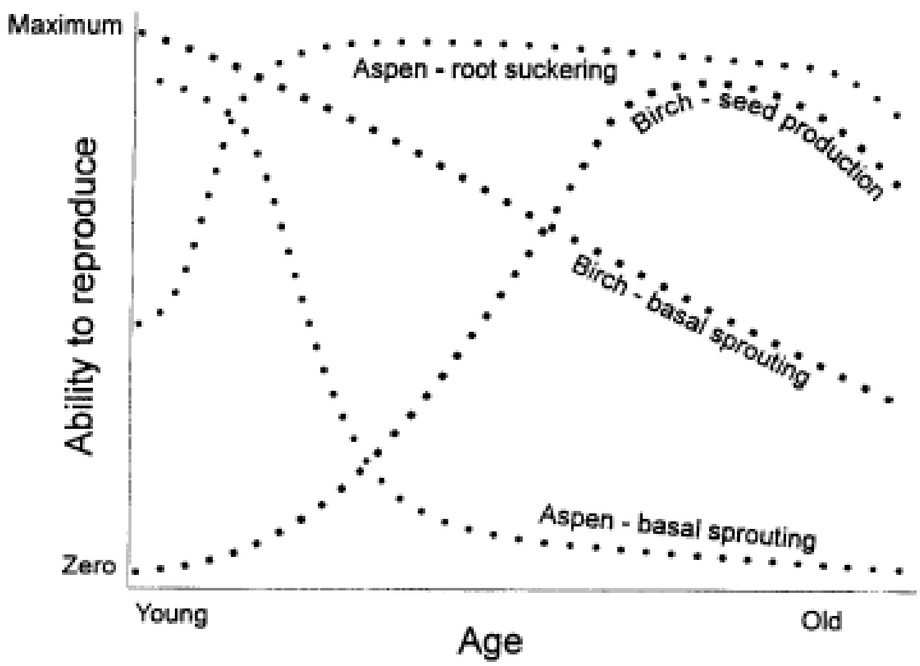

FIGURE 2.1. Comparison of aspen and birch reproductive strategies. As aspen stands mature they maintain a high capability to produce root suckers, but the ability to produce basal sprouts from aspen stumps drops off rapidly during aspen stand development. As stand age increases, basal sprouting from birch stumps drops off less dramatically than in aspen. Increasing capacity for seed production is a prominent feature in birch stand development but it is unimportant in aspen (Haeussler 1991, based on Zasada et al. 1992).

2.2. Birch

Birch's key reproductive features are highlighted below based on information previously summarized by Perala (1990b, 1990c), Safford et al. (1990), Simard (1996a, 1996b), and Peterson et al. (1997).

- Birch has regeneration advantages over its companion conifers because it can effectively reproduce from seeds or sprouts. In addition to seed reproduction, adventitious buds can vigorously sprout from the root collar following cutting or fire. Birch reproduction is mostly from seed. It begins to bear seed by age 15 years and optimum seed production occurs between ages 40-70 yr. Birch produces seeds annually but good crops every 2-4 years. Solitary birch trees produce about ten times more seed per tree than trees in closed stands.
- Birch, like white or Engelmann spruce, has a fall and winter seed dispersal pattern. This contrasts with aspen and cottonwood that disperse seeds in early summer. Moist, mixed mineral-organic soil is the ideal medium for birch seed germination. Such seedbeds are created following windthrow, fire, and mechanical site preparation.
- Birch of seed origin grow much slower than those of sprout origin due to the smaller carbohydrate reserve in the root system of a seedling compared to a sprout attached to the established root system of a former tree. In British Columbia's ICH Zone, seedlings on mesic sites grew on average only 20 cm/year whereas sprouts grew on average 60 cm/year. In general, natural regeneration can be effective on small patch cuts or if seed trees are left in place. However, regeneration may be poor in large openings.
- Birch sprouts from the root collar or stump following fire or cutting. This origin of birch stems is indicated where stands are made up of multi-stemmed clumps. Numbers of birch sprouts per cut stem are commonly reported to range from 2-15 sprouts per stump. However, in the ICHmw3 variant, up to 200 sprouts per cut stump have often been recorded but these sprouts rapidly thin to 3-7 per stump within 10 years of cutting.
- Birch gradually loses its ability to regenerate vegetatively after approximately 60 years old. In this context it is important to note aspen and birch differences. Although aspen can vigorously produce root suckers in stands 100 or more years old, aspen's ability to produce basal sprouts declines to near zero by age 100 (Figure 2.1). In contrast, in birch 30-40% of stems 100-150 years old still have the ability to form basal sprouts. Very severe fires that completely remove organic layers, leaving only charred roots, prevent further basal sprouting in birch.
- Sprouting is believed to be more vigorous if birch trees are cut in the dormant season. Prolific sprouting occurs when trees are young but sprouting vigor declines with age.
- High light intensity and high temperatures stimulate the growth of sprouts so that growth of birch is faster after clearcutting than it is after thinning. Sprouts can reach 1 m in the first growing season and are often twice the height of

seedlings by age 4. Birch stems of sprout origin that have height growth rates as great as 1 m/year are common in mesic and wetter sites.

Birch's regeneration features are influenced by its tolerances to several of the key variables summarized in Table 2.2.1 and overall silvical characteristics listed in Table 2.2.2.

TABLE 2.2.1. Birch tolerances to several key variables, based on Klinka et al. (2000).

Tolerance to	Tolerance class*	Comments
low light	M	probably moderately shade tolerant
frost	H	frequent on sites with growing season frost
heat	M	in warmer climates it is infrequent on insolated sites
water deficit	M	infrequent on dry sites; responds to drought by shedding leaves
water surplus	H	infrequent on wet sites; tolerates flooding and sites with a strongly fluctuating water table
nutrient (mainly N) deficiency	M	absent in acid, very poor soils; a nutrient-sensitive species

* L – low; M – medium; H - high

TABLE 2.2.2. Birch's key silvical characteristics, based on Klinka et al. (2000).

Silvical characteristic	Interpretive class	Comments
reproductive capacity	H	reproduces vegetatively from stump sprouts; minimum age for a seed crop is about 15 yr; optimum seed bearing age is 40-70 yr; seed crops are heavy and infrequent
seed dissemination capacity	H	dispersed by wind, particularly when blown over snow surfaces
potential for natural regeneration in low light	L	practically nil in absence of adequate seedbeds
potential for natural regeneration in the open	H	good if exposed mineral soil or burned forest floor present
potential initial growth rate	M	best growth (about 40 cm/yr) occurs in partial shade and on burned forest floor seedbeds
response of advance regeneration to release	NA	advance regeneration does not develop without adequate light and seedbeds
self-pruning capacity in dense stands	M	dense stands are infrequent
crown spatial requirements	M	varies with stand density
light conditions beneath closed-canopy, mature stands	H	associated with well developed understory vegetation
potential productivity	M	site index functions for BC not available; site index (50 yr @ bh) may be 35± m on most productive sites
longevity	L	matures at about 70 yr; few individuals live longer than 200 yr

2.3. Cottonwood

Compared to aspen and birch, cottonwood has the most diverse regeneration adaptations of these three hardwood species. Cottonwood's key reproductive features are highlighted below based on information previously summarized by McLennan and Mamias (1992), Niemiec et al. (1995), and Peterson et al. (1996).

- Cottonwood is very successfully reproduced by seed production, providing suitable germination conditions are available. Under natural conditions seeds of cottonwood have relatively short longevity.

- Cottonwood first produces seed at approximately 10 years old. Good seed crops are produced annually. The timing of seed dispersal in relation to timing of flood deposition of sandbars is one determinant of cottonwood seedling establishment in riparian areas.

- Prime habitat for cottonwood seedling establishment is sediment exposed along stream channels by receding water levels in late spring. Cohorts of seedlings that develop in these linear habitats adapt to survive subsequent deposition of sediments by forming new root systems further up the stem.

- Moist mineral seedbeds are crucial for high germination in cottonwood, and seedling survival depends on continuously favourable seedbed conditions during the first month.

- Cottonwood commonly reproduces vegetatively by sprouting from stumps and from partially buried twig, branch, and stem fragments lodged in alluvial parent materials. Cottonwood also has a unique form of vegetative reproduction, referred to as cladoptosis (Galloway and Worrall 1979), which involves the physiological abscission of lateral twigs. These twigs, with leaves attached, can take root if they fall on moist soil. This may be one means for cottonwood to colonize moist sandbars.

- Cottonwood establishes only infrequently from root suckers and is therefore not as well adapted as aspen for regeneration after fire. Reports of cottonwood root suckers exist in the literature but suckers are sufficiently uncommon that some researchers doubt that this subspecies has them at all. Suckering by this species was not recorded in any of the reports reviewed by Rood and Mahoney (1991) for southern Alberta. However, Gom and Rood (1999b) have subsequently documented suckering after fire in cottonwood stands. There are also records of root suckering along the margins of cottonwood stands near the Kootenay River (J. Braatne and M.L. Polzin, pers. com.).

Cottonwood's regeneration features are influenced by its tolerances to several of the key variables summarized in Table 2.3.1 and overall silvical characteristics listed in Table 2.3.2.

TABLE 2.3.1. Cottonwood tolerances to several key variables, based on Klinka et al. (2000).

Tolerance to	Tolerance class*	Comments
low light	M	probably moderately shade tolerant
frost	H	frequent on sites with growing season frost
heat	M	in warmer climates it is infrequent on insolated sites
water deficit	M	infrequent on dry sites; responds to drought by shedding leaves
water surplus	H	infrequent on wet sites; tolerates flooding and sites with a strongly fluctuating water table
nutrient (mainly N) deficiency	M	absent in acid, very poor soils; a nutrient-sensitive species

* L – low; M – medium; H – high; NA – not applicable

TABLE 2.3.2. Cottonwood's key silvical characteristics, based on Klinka et al. (2000).

Silvical characteristic	Interpretive class	Comments
reproductive capacity	H	high potential for vegetative reproduction from root and stump sprouts; flowering begins about 10 yr old
seed dissemination capacity	H	readily dispersed by wind and water
potential for natural regeneration in low light	L	practically nil; a shade-intolerant species that requires light exposure
potential for natural regeneration in the open	H	especially good on mineral soil; buried stem segments and branches greatly contribute to regeneration
potential initial growth rate (≥ 5 yr)	H	up to 2 m in one growing season in cuttings
response of advance regeneration to release	NA	advance regeneration does not develop without adequate light
self-pruning capacity in dense stands	H	if initial stand density is high
crown spatial requirements	H	short but wide crown is necessary to support rapid growth
light conditions beneath closed-canopy, mature stands	H	associated with well-developed understory vegetation
potential productivity	H	site index (50 yr @ bh) >30 m on productive sites
Longevity	L	generally <200 yr

3. SERAL SEQUENCES FOLLOWING HARDWOOD ESTABLISHMENT

There are so many different seral sequences involving aspen, birch, or cottonwood after disturbances that only highlights can be covered in a short review. Those highlights focus on disturbances from fire, forest harvesting or silvicultural practices, flooding, and industrial or other land disturbances. The comprehensive review of forest stand dynamics by Oliver and Larson (1990) gives many examples from western North America to demonstrate that vegetation patterns across a landscape are neither completely random nor completely predictable.

3.1. Succession in Natural Stands Between Fire Intervals

Relative shade tolerances of tree species provide a guide to their role and persistence in mixed stands as succession proceeds between disturbances. Data compiled by Kobe and Coates (1997) from the ICH Moist Cold Biogeoclimatic Subzone in the Smithers area provide a quantitative measure of the effect of shade tolerance of key tree species. The strength of these data is their reliance on quantitative measures of shade tolerance, based on species differences in tree mortality rates, in contrast to the usual qualitative estimates of shade tolerance based on subjective observations. These investigators ranked key tree species in northwestern British Columbia as follows, from most shade tolerant to least shade tolerant: **western redcedar > western hemlock = subalpine fir > hybrid spruce > lodgepole pine > aspen > cottonwood = birch.** In southeastern British Columbia, response of birch seedlings to varying light conditions has been studied by DeLong et al. (2000a) but this study did not focus on a shade tolerance ratings of these species.

To put these Kobe-Coates shade tolerance ratings in perspective, at low growth rates mortality under shade was an order of magnitude greater in birch than in western redcedar. It is known that shade tolerance may vary with site conditions, especially soil moisture, but the Kobe-Coates mortality model is consistent with previous qualitative estimates of shade tolerance classes and confirms the dominance of different species at different stages of post-disturbance succession. For the CBFWCP area, the important point is that aspen, birch, and cottonwood all fall in the least shade tolerant end of the range. Clearly, these three hardwoods do best in open, un-shaded sites.

Non-shaded conditions that favour hardwoods are created by various disturbances, especially fire. Within the CBFWCP area, mean fire return intervals vary widely between biogeoclimatic zones, as indicated by Parminter (1992) data summarized in Table 3.1. For stimulation of hardwood regeneration, surface fires are more relevant than crown fires, but data on mean return intervals of surface fires are available for only the PP and IDF Zones (Table 3.1).

In the PP Zone crown fires are rare and average fire return intervals for surface fires is 5-15 years, with average fire sizes ranging from 5-50 ha. In the IDF Zone average fire return interval for surface fires is 10-20 years, with average fire sizes also small (5-50 ha) as in the PP Zone (Table 3.1).

For the ICH, MS, SBS, and ESSF Zones, data compiled by Parminter (1992) do not allow distinction between return intervals of crown *versus* surface fires. For crown and surface fires combined, in the MS, SBS, and ESSF Zones fires average 50-500 ha and in the ICH Zone fire size averages 150-500 ha. Average fire return intervals are 100-150 years in the SBS Zone, 150-250 years in the ICH Zone, 175-275 in the MS Zone, and 200-300 years in the ESSF Zone (Table 3.1).

What do these biogeoclimatic zone differences in fire return intervals mean for hardwood species in the CBFWCP area? Section 4 highlights some distinct differences in age-class structure for aspen, birch, and cottonwood in the Nelson Forest Region. It was beyond the scope of this review to explain the various Forest District differences in age-class distributions of these hardwoods, but it is reasonable to hypothesize that most of the current age-class distribution is a result of regional and local variations in fire history. More detailed age-class analyses are presented in Appendix III and in Section 4.3 of the main report.

TABLE 3.1. Typical historic patterns of wildfire disturbance by biogeoclimatic zone in the CBFWCP area, based on data compiled by Parminter (1992).

Data quantity & quality	Fire type	Fire intensity	Mean fire return interval (yrs)			Fire size (ha)	
			Min	Avge	Max	Avge	Max
ESSF Zone							
Good	Surface	Low-medium	150-200	200-300	350-500	50-500	10,000
	Surface & crown	Medium-high					
MS Zone							
Medium	Surface & crown	Medium-high	125-175	175-275	275-350	50-500	>5000
PP Zone							
Very good	Surface	Low	4-5	5-15	15-25	5-50	50-150
	Crown	Medium-high	Rare	Rare	Rare	5	5-50
IDF Zone							
Medium	Surface	Low	5-10	10-20	20-50	5-50	50
	Surface & crown	Medium-high	100-150	150-250	250-350	50-500	>5000
ICH Zone							
Good	Surface	Low	100-150	150-250	250-350	150-500	>25,000
	Surface & crown	Medium-high					
SBS Zone							
Medium	Surface & crown	Medium-high	75-100	100-150	150-250	50-500	15,000

3.1.1. Aspen

Unlike tree stems of seed origin, cohorts of asexual stems in aspen clones have very low survivorship after the first year. Steneker (1976) gave examples of initial sucker densities ranging from under 50,000 to over 200,000 suckers/ha in year 1, but in every case by year 5 or 6 densities were reduced to 30,000-40,000 stems/ha. Navratil (1991) published similar data in which a broad range of aspen studies showed a consistent reduction of sucker density to about 6,000 stems/ha by age 20, whether initial density in year 1 was 20,000 or 200,000 suckers/ha. Typically the least vigorous suckers die in the first 1 or 2 years, leaving only one or two dominant suckers in each clump. Competition reduces most clumps to a single sucker by the fifth year (Peterson and Peterson 1992). Greene et al. (1999) indicated that this rapid reduction in sucker density was due to competition for shared carbohydrates in the clonal root system rather than competition for light (at least during the first 5 years).

The exceptionally wide range of recorded initial sucker densities was thought by Greene et al. (1999) to be a function of pre-fire aspen basal area density and time since burning. Studies of aspen's responses following the 1988 Yellowstone fires indicate that not all aspen clones are predisposed to prolific growth after fire, and the response is predictable based on pre-burn stand root biomass or aboveground basal area of aspen stems. Data presented by Renkin and Despain (1996a) suggest a pre-burn basal area of about 25 m^2 of aspen stems/ha or a root biomass of 20 tonnes/ha are required for optimal aspen regeneration following fire. Repeated fires appear to increase the number of aspen sprouts per unit area per fire event, although vigor of sprouts is less after subsequent burns than following an initial burn (Perala 1974).

The future of aspen in the CBFWCP area may be dependent on several things learned from the detailed Yellowstone studies since 1988. It is now known that simply burning aspen does not ensure adequate densities and growth rates to overcome herbivory in places where elk browsing can be high. Also, herbivory alone does not universally result in either accelerated sucker mortality or the elimination of aspen from a given site. Renkin and Despain (1996a) concluded that when suckers are browsed, resources are directed into the production of new suckers rather than the continual height growth of protected suckers produced in the first year after a fire. However, recent studies in Banff National Park indicate that aspen-elk-fire relationships may be more complicated than that (Kay et al. 1994).

Aspen does not commonly grow from seed due to its demanding seedbed requirements (Perala 1990; Kay 1993). It is thought that conditions have not been conductive to aspen seedling growth and clonal establishment since shortly after the last major glaciation 10,000 years ago (McDonough 1979, 1985). Aspen in the Rockies, including the Elk Valley, would appear to have maintained themselves over thousands of years via vegetative regeneration. If this is the case, then aspen clones may be fire dependent in the long term. The area occupied by aspen in Yellowstone National Park has declined by 95% since 1872 (Kay 1990), due primarily to fire suppression. Aspen regeneration occurs with regular, low intensity fires; with fire suppression, conifers invade aspen sites and the eventually replace the aspen stands (Kay et. al. 1994). Without regeneration by seed, the site may not return to aspen even when a fire runs through the conifer stand, if all the live aspen have been removed by competition with conifers. The potential for aspen roots to survive under conifer stands, longer than the fire cycle in any particular biogeoclimatic zone, is not known and is a critical factor in understanding the long term ecology of aspen-conifer stands. We are not aware of documented cases of aspen sucker regeneration where there is absolutely no aboveground evidence of aspen presence, but Horton (1956) did record examples on the east slope of the Rockies in Alberta where sparse and very inconspicuous aspen suckers were the only indication of a functional belowground aspen root system in what was by all appearances pure conifer stands. Schier et al. (1985) also documented cases in the western United States where aspen root systems may persist in the absence of canopy aspen, nurtured only by transient suckers beneath a coniferous canopy. The longevity of aspen root systems in the absence of aspen in the canopy has been known for a long time, but there is little or no experience with silvicultural manipulation of this reproductive resource (Peterson and Peterson 1992).

Kay et. al. (1994) suggested that aspen was maintained over the last several centuries by spring burns started by native people in the Rocky Mountains. However, some researchers question whether spring burns by native people were a major factor in maintaining aspen stands (W. Choquette, pers. comm.). Steve Barrett, University of Montana, interviewed native elders of the Flathead and Kutenai tribes and found that natives burned deliberately only to maintain areas that produced medicinal plants. However, if the arguments provided by Kay et al. (1994) are true, it implies that if aspen systems in the Elk Valley are not managed with fire it is likely that they will eventually disappear. There may also be other influences on aspen's sustainability. Kay et al. (1994) indicated that elk grazing of aspen systems in Banff National Park has reduced fine fuels that carry fires and has also eliminated aspen re-sprouting by browsing. This is another long-term concern in the Elk Valley if high elk populations are maintained.

These recent observations by Kay and co-workers suggest that aspen's age class distributions are not totally a result of fire or harvesting disturbances. Recent syntheses of ecological implications of fire in the Greater Yellowstone ecosystem indicate that the abundant aspen stands that originated there between 1870 and 1890 may have been a result of a very intensive hunting and trapping era that markedly reduced elk and beaver populations, thereby favouring aspen development (Knight 1996).

Pure aspen stands are often considered to be natural fireguards during the growing season because they are less likely to burn than aspen growing in more fire-prone conifer dominated stands (DeByle et al. 1987). Aspen is a fire-adapted species because its roots are seldom damaged by fire, heat generated by fire actually stimulates root-sucker production, and aspen stands do not support rapidly spreading or intense fires (Fechner and Barrows 1976). These investigators indicated that crown fires drop to the ground when they reach aspen stands and, except in the autumn when there is dry understory vegetation and aspen leaf fall on the surface, most fires extend only a short distance into aspen stands. As one example of the fire-proof differences between aspen and conifer stands, in the period from 1960-1973 in the Colorado National Forest only about 5% of

4590 fires occurred in aspen stands, whereas 10% occurred in brush and grass areas, and 85% occurred in coniferous forests (Fechner and Barrows 1976).

Aspen stands do burn but, because height to the base of aspen crowns increases with stand age, stands with low recruitment of understory conifers become less susceptible to crown fires as they age (Cumming 2001). Fires in the aspen fuel type, as defined by Alexander and Maffey (1992/93), have typically low susceptibility to surface fires even under relatively severe burning conditions. The greatest chance of fire in pure aspen stands is in autumn after leaf fall and after understory vegetation is cured. Dead and downed roundwood fuels are a relatively minor component of the fuel complex in pure aspen stands. Fires can occur in pure aspen stands in spring but they are often deterred by high moisture content of the duff layer (Alexander 1982; Quintilio et al. 1991).

There is current interest in whether aspen is a stable vegetation type. For example, what are the options for maintaining pure aspen stands over the long term in locations such as the Elk Valley or Robson Valley? Aside from harvesting, and perhaps also prescribed burning in some parts of the Elk Valley, are there ways to stop or delay succession to conifers in locations where long-term maintenance of pure aspen is the goal? Debate on whether aspen is a ‘temporary’ or ‘permanent’ forest type commenced early in the North American forestry literature. The first observations were that: aspen is one of the most light-demanding (least shade tolerant) tree species; it is well adapted to establishment in open areas by vegetative reproduction from adjacent existing stands or by seeding in; and is often replaced by conifers as succession proceeds. Fetherolf (1917) was probably the first to publish an article on *Aspen As a Permanent Forest Type*. He observed that fire can markedly set back conifer succession but can also encourage aspen sucker production. However, he also noted that conifers would not replace all aspen if fires were kept out.

Since these early observations there are now textbooks devoted solely to the dynamics of forest stands (Oliver and Larson 1990). It is obvious that Fetherolf’s suggestion that aspen can be considered a permanent forest type has withstood the test of time. Some United States aspen researchers actually distinguish tree dynamics in ‘seral’ versus ‘stable’ aspen stands (Harniss and Harper 1982). The permanence of aspen in the landscape is shown by the comparison of historical and current forest cover in the U.S. portion of the Columbia River Basin (Hessburg et al. 1999; Hessburg and Smith 1999). These comparisons indicate that the aspen-cottonwood forest cover type is maintaining or increasing its presence over the landscape. Hessburg and Smith (1999) indicate that for the Northern Glaciated Mountains Ecological Reporting Unit (the portion of the U.S. Columbia Basin bordering British Columbia) the aspen-cottonwood type represented 0.3% of the landscape in the historical period (1932-1966) but has increased to 1.9% in the current reporting period (1981-1993).

Research into the reproductive potential of clonal aspen root systems continues to be an active field of research in the western United States especially because of efforts in aspen restoration in places where this species is now in decline (Shepperd 1993a, 1993b; Kay 1994; Shepperd 1996; Kay 1997b; Bartos and Campbell 1998; Bartos and Shepperd 1999; Ripple and Larsen 2000; Bartos In press; Renkin In press; Shepperd In press).

3.1.2. Birch

The key features of birch's responses to fire disturbances are summarized below, based on information documented in Simard and Vyse (1992) and Peterson et al. (1997).

- Birch is very shade intolerant and hence usually lasts only one generation in natural succession. However, through regeneration in stand openings (see Section 7.2) birch can be present in older mixedwood stands by regenerating in stand gaps that have been created by blowdown or root-rot mortality of conifers.
- Dense even-aged stands of birch can quickly develop after a disturbance but once established little ingress occurs. As a result many mature birch stands are characterized by a lack of stems in younger age classes. As with other shade intolerant species, birch's shade intolerance becomes more pronounced with increasing stand age.
- At the landscape level, the dominant disturbance responsible for the current interior British Columbia patch pattern of birch was wildfire occurrence and settlement patterns at the turn of the century. Wildfire has largely been eliminated by fire suppression programs and replaced by smaller scale disturbances such as root disease, windthrow, clearcutting, selective weeding, and cattle grazing. As a result, birch in maturing fire-seral forests is nearing its natural ecological rotation age (60-70 years) and is gradually being replaced by late-succession conifers. However, in many older stands birch does persist in pockets created by root diseases or other local disturbances. In recent clearcuts, regenerating birch is fragmented in small patches and often reduced to very small components of any given site series.
- Although birch can reach ages of about 150 years, this species often begins to decline about 70 years after the disturbance that provided circumstances favourable to birch vegetative or seedling reproduction.
- Late-stage succession is obviously dependent on long intervals between fires. Reduced fire frequency can influence the successional pathway of stands that include birch. When the fire return interval is short, stands that contain birch (or aspen) usually burn while still in the even-aged stage of development, and tree regeneration after a burn tends to be the same species as before the burn. In contrast, where intervals between fires are longer, successional pathways are increasingly influenced by canopy openings caused by wind, insects, or diseases.
- Fire and other disturbances that expose mineral soil favour birch seedling establishment and sprouting from surviving roots. Birch can be an aggressive pioneer when it is not overtopped by shrubs; in dense young birch stands, birch can be a strong competitor with understory conifers, particularly those that are moderately or highly intolerant to shade.
- Stands with birch tend to burn only under special conditions such as in early spring before bud burst, following severe drought, or late in stand history when the proportions of conifers are greater.

- In some areas of British Columbia's interior wet belt, mixed stands develop where veteran and/or adjacent conifers and birch survive the fire, and both disperse seed onto heterogeneous seedbeds created by complex fire behaviour. In this successional sequence, the presence of birch is characterized by a lack of birch in small size classes.
- In general, young stands of pure birch are relatively uncommon in British Columbia; this is partly due to fire suppression and conifer-centred silviculture practices during the past several decades.

3.1.3. Cottonwood

In general, fire disturbance is much less prevalent in cottonwood stands than in ecosystems where aspen or birch is predominant. Research nearest to the CBFWCP area is the work by Rood and co-workers on fire effects in southwestern Alberta cottonwood stands. There is evidence that fire induces clonal sprouting of riparian cottonwoods, based on studies by Gom and Rood (1999b) along the Oldman River in southwestern Alberta. Although *Populus* species identification is difficult in that area, both black cottonwood and balsam poplar are known to be present. Both of these subspecies belong to the Section Tacamahaca of the genus *Populus* (Dickman and Stuart 1983). Gom and Rood found that after fire in April, prior to bud flushing, cottonwoods responded by vigorous sprouting especially in the first summer. Five years after the burn, the number of clonal sprouts was reduced by about half and surviving sprouts averaged 3 m in height. In the first season 90% of the sprouting trunks was from Tacamahaca hardwoods (in contrast to the Section Aigeiros, represented by *Populus deltoides*). After five years it was evident that Tacamahaca hardwoods produced many more sprouts and had better survival than *P. deltoides*. Gom and Rood (1999b) report this superior ability of the Tacamahaca cottonwoods to regenerate after burns has been observed elsewhere from northern British Columbia to southern Utah.

At least in southwestern Alberta, riparian woodland flammability varies seasonally. Gom and Rood (1999b) believed that fire is least hazardous in winter or in late spring when conditions are moist and tree water status is favourable. Cottonwood woodlands are probably most flammable in autumn and early spring when conditions are dry and the trees are quiescent. Thus fires would naturally tend to occur at times when riparian cottonwoods are most capable of sprouting.

Fire fundamentally changes the character of a riparian cottonwood grove. As cottonwood stems are easily girdled, the mature canopy can be lost even in low intensity surface fires. However, clonal cottonwood sprouts will generally result in grove regeneration over a few decades. The pulse of sprouts produced after burning is similar to an episodic recruitment of seedlings following floods. Since the rate of clonal sprout growth (about 1 m/yr) is much more rapid than seedling growth (about 0.3 m/yr) the cottonwood woodland can rebound quickly (Rood et al. 1998). Thus, periodic fire occurrences might have a net benefit for some riparian woodlands, particularly those composed of healthy Tacamahaca cottonwoods.

The Ktunaxa ethnobotany and fire ecology study (Mah 1997), as part of the East Kootenay Trench Restoration program, did not uncover details of aboriginal burning in cottonwood ecosystems. However, based on an electronic bibliography compiled by G.W. Williams (see www.bloorstreet.com/300block/aborcan.htm) Mah lists clearing of riparian areas as one of 11 documented reasons for burning by aboriginal people. Presumably this would have occurred in some of the cottonwood areas of southeastern British Columbia.

3.2. Succession Following Forest Harvesting and Silvicultural Practices

This section does not review successional sequences following harvesting of hardwood stands because there appears to be little current interest in commercial use of hardwoods in the CBFWCP area. The points below refer to hardwood regeneration responses when conifers are removed from stands in which hardwoods are now present.

Substantial research in southeastern British Columbia has focused on ways to enhance biodiversity by different silvicultural approaches. Details of that research by the Ministry of Forests and the Ministry of Environment, Lands and Parks are beyond the scope of this review. However, some examples of the place of hardwoods in current forest management planning are given below.

Forest harvesting and silvicultural practice impacts on hardwood distribution and abundance will be influenced by site productivity relationships for the hardwood species involved in a given location. Section 5.9 outlines differences in frequencies of occurrence of aspen, birch, and cottonwood in relation to soil moisture and soil nutrient classes (Figure 5.9.2). Section 3.6.0 of Fraser and Davis (1996) summarized volume data to indicate how aspen, birch, and cottonwood are distributed on good, medium, and poor sites. Those summaries are presented for individual hardwood species in Table 5.9.1.

Development of mixed stands following a large-scale disturbance in the southern interior of the province usually involves: rapid establishment of many species within 5-10 years; early dominance of shade-intolerant species such as birch; early suppression of shade-intolerant understory; establishment of shade-tolerant species such as western redcedar; later creation of small openings due to mortality of birch or aspen (typically after 40 or more years); release of suppressed shade-tolerant conifers; and subsequent re-sorting of species size hierarchies over time as birch drops out and longer-lived conifers occupy the upper canopy. With 14 native tree species in the ICH Zone, the successional sequences outlined above indicate the potential for a wide variety of stand structures. The numbers and proportions of the constituent species vary widely, even for stands initiated by the same disturbance (Cameron 1996).

Measurements of even-aged 10-year-old stands in the ICH Zone of southern interior British Columbia showed that increasing birch density had strong effects on the size of neighbouring shade intolerant western larch, moderate effects on the size of moderately shade tolerant Douglas-fir, and little effect on the size of shade tolerant western redcedar (Simard 1996a, 1996b). Mixed-species stands, which are typical of birch's occurrence in most of British Columbia, generally have greater variation in vertical structure than single-species stands (Cameron 1996). Although details are not well known, there are indications that use of birch by hares, deer, and moose can have an important effect on stand density and structure of young birch stands (Machmer and Steeger 1995).

Several other harvesting or silvicultural responses of birch have also been documented:

- Birch readily seeds into areas with soil disturbances caused by logging, slash burning, and mechanical site preparation. On sites where birch seeds-in densely or has sprouted from stumps, it can out-compete conifers. It may inhibit conifers where areas disturbed by harvesting and silvicultural practices are located near stands of mature birch trees, or where residual birch is left on-site to allow seeding-in.
- The other main kind of succession involving birch is in relation to small-scale disturbances. Birch does not reproduce well in established forests and in such forests birch only occurs in later stages of forest succession where gaps are created in the canopy following disturbances such as blowdown, fire, root disease, or insect-kill of conifers. Birch does regenerate in small gaps but does not grow well there. In small gaps, western redcedar, western hemlock, and other conifers may be released from their suppressed position in the understory; in larger gaps, birch may regenerate where mineral soil is exposed and where open light requirements exist.
- Birch is shade intolerant and therefore pure stands usually last only one generation without further major disturbance, and then are succeeded by understory conifers. In the southern interior of British Columbia, there are common examples of birch stands succeeding to variable and complex mixtures that include one or more of western redcedar, western hemlock, Douglas-fir, western white pine, or western larch. Birch is a common component of climax forests where gaps have been created by disturbances such as blowdown, fire and root rot.

3.3. Succession Following Flooding

Considerable information exists relevant to the CBFWCP area about post-flooding succession in riparian cottonwoods (Bradley and Smith 1984, 1986; Fyles and Bell 1986; Rood and Mahoney 1990, 1991; Mahoney and Rood 1998; Rood et al. 1994, 1995; Braatne et al. 1996; Johnson 1997; Mahoney 1997; Merigliano 1998; Gom and Rood 1999a, 1999b, 1999c; Law et al. 2000).

From the references cited above, a key point is that recruitment of cottonwood seedlings is dependent on dynamic fluvial processes. Cottonwood seedling establishment regularly occurs on sediment exposed along stream channels by receding water levels in late spring. Similarly aged cohorts of seedlings develop in these linear habitats. A further adaptive advantage of cottonwood in these situations is the ability of its roots to grow 1 cm/day, an adaptation that keeps roots in moist soil as flood levels drop. If river levels decline too rapidly, cottonwood seedlings quickly succumb to drought. They are also adapted to survive subsequent deposition of sediments by forming new root systems further up the stem (adventitious rooting).

Cottonwood, a common species on flood-prone habitats, has all the characteristics of an early successional species: prolific seed production; positive regeneration response to soil disturbance; rapid juvenile growth; low shade tolerance; good self pruning; relatively short life span; and later replacement by shade tolerant associates.

Succession following flooding provides a good example of how repeatable patterns of stands across a landscape can appear uniform but they can also vary in a fine-scale or coarse scale (Oliver and Larson 1990). For example, in the CBFWCP area alluvial sites where cottonwoods occur could have conspicuous small-scale variations since soil variations resulting from flood levels can create many small stands of different age classes, but the large-scale variation is small because similar stands appear over large linear valley-bottom areas. In contrast, narrow aspen stands that can occur along streams dissecting a biogeoclimatic zone characterized by upland ponderosa pine stands may have little variation within each aspen stand on a small scale but large variation on the broad scale when contrasting the aspen with adjacent pine stands.

Cottonwood may be a competitor with conifers because of its rapid height growth and early dominance of forested alluvial sites. Cottonwood stems may be very dense in the first few years of growth but self-thinning normally occurs by age five. It is generally not found as an understory species beneath mature forest canopies. Cottonwood trees cut during logging sprout profusely from stumps and in some situations may produce root suckers. Cottonwood must maintain a dominant crown position to survive and grow.

4. POTENTIAL AGE CLASS DISTRIBUTIONS OF HARDWOODS

Current age-class distributions of hardwoods in the CBFWCP area are detailed in Appendix III and in Section 4.3.2 of the accompanying report. Some generalizations from the literature are summarized below.

Although not dealing specifically with aspen, birch, or cottonwood age-class structure following fire, Van Wagner's (1978) article *Age-Class Distribution and the Forest Fire Cycle* is fundamental to understanding this subject. Also, the text by Oliver and Larson 1990) provides several generalizations about age-class structure of single-cohort, shade-intolerant species such as aspen, birch, and cottonwood. The relevant generalizations are listed below.

- The frequency and magnitude of disturbances dictate the age distributions of stands in an area, and single cohort stands are a result of specific cases of disturbances.
- Disturbances occur in a continuum of intensities from slight to very great. A single cohort stand can result from either a disturbance that removes all previously existing stems or a disturbance that removes so few stems that the

remaining ones rapidly re-occupy the growing space and preclude entry of new cohorts.

- The frequency of disturbances relative to the life spans of component trees determines the age distribution of stems.
- The age range in single cohort stands is narrow when the first invading stems rapidly occupy the growing space. Narrow age ranges occur where sites are productive, where the species present have regeneration mechanisms that promote rapid growth, and where many trees establish soon after disturbance.
- Favorable site conditions and abundant reproductive material (root or stump sprouts, advance regeneration, or seed sources) allow most stems to be established early and grow rapidly, leaving little growing space for other stems to be established later.
- An aggregation of many small stands of comparable size, each a result of an annual disturbance, could produce an all-aged forest. In such a theoretical case, each patch acts as an isolated, single cohort stand. More realistically, cohorts would be irregularly distributed in time if disturbances were strong enough to create a new age class at irregular intervals.

What do these generalized concepts of forest stand dynamics mean for the CBFWCP area? First, it is evident that many of these generalizations apply to stands where aspen, birch, or cottonwood are present. Second, there is another overall important generalization. Where a disturbance affects a large proportion of forests in an area it can leave a clumped distribution of single cohort stands, or a cohort of similar age and species composition within many multi-cohort stands (Oliver and Larson 1990). This is what happened following the 1988 fires in the Greater Yellowstone area (Greenlee 1996). Since stands change in susceptibility to disturbances as they develop, the similar stands or cohorts can be destroyed by a single disturbance which can result in several different age cohort stands occurring within an otherwise single-age cohort dominant over the landscape. Research to verify this circumstance was beyond the scope of this review, but it is likely that such a condition is prevalent within the CBFWCP area. That is, there are likely many stands of aspen, birch, or cottonwood within various Landscape Units in the CBFWCP area that are deviant from the age-class structure shown as an overall average for these species in the Nelson Forest Region (Table 4.1).

As shade intolerant species, aspen, birch, and cottonwood are not well suited to recruitment of new age cohorts either under their own canopies or under canopies of mixed conifer-hardwood stands. However, these hardwoods have regeneration advantages over conifers because they possess both vegetative and seed reproduction strategies. This adeptness at regeneration under non-shaded conditions means that age-class structure of these hardwoods is strongly influenced by the frequency and intensity of disturbances that allow shade intolerant species to reproduce and develop. A result is a tendency for individual stands of aspen, birch, or cottonwood to be cohorts of a fairly narrow range of ages. However, at a landscape level there can be sufficient variations in timing and intensity of disturbances to allow a given Landscape Unit to contain a wide variety of different aged hardwood stands coinciding with disturbances at different times in the past.

As indicated above, age-class distributions of aspen, birch, and cottonwood are strongly controlled by disturbance history that varies regionally and over time. Therefore, there is no single representative age class structure for these hardwoods. The only consistent feature is very low representation of age classes over 120 years, especially for aspen and birch.

For the CBFWCP area the simplest way to visualize the possible kinds of hardwood age classes is to examine existing age-class distribution. Table 4.1 summarizes percentage representation in each age class for each species, based on "weighted net area" as defined by Fraser and Davis (1996). They presented age-class distribution data separately for each forest district and for TFL lands, but in Table 4.1 the values are averaged to give an estimate of age-class distribution of each species for the Nelson Forest Region, excluding the Boundary Forest District. These region-wide age class distributions for aspen, birch, and cottonwood are portrayed by histograms in Figure 4.1.

There are several key species differences shown by the summaries in Table 4.1:

- Aspen and birch are both heavily represented by age classes 80 years or younger – about 90% of aspen and birch are under 80 years old – compared to about 50% of cottonwood in age classes less than 80 years.
- Less than 11% of aspen or birch is 120 or more years old but about 30% of cottonwood exceeds 120 years, with about 2% over 250 years, based on "weighted net area" determined by Fraser and Davis (1996).
- Compared to aspen and birch, cottonwood has a relatively high representation in the 1-20 year age class (29.6%). A possible reason is that the relatively lower representation of aspen or birch under 20 years old is a result of recent fire suppression, whereas fluvial events that lead to cottonwood regeneration are not influenced by fire suppression activities. An alternative hypothesis is that logging at low elevations, especially in the Revelstoke area, is providing substantial areas suitable for cottonwood regeneration. The high average representation of cottonwood under 20 years old is geographically focused in the exceptionally high amount of young cottonwood in the Columbia Forest District and on TFL lands. Reasons for this relatively high representation of young cottonwood stands requires further investigation.

Section 3.7.0 of Fraser and Davis (1996) shows some geographic anomalies in age-class distributions which are masked by the Nelson Forest Region averages given in Table 4.1. This review could not include research to explain these anomalies but they include:

- Compared to other forest districts, there is an unusually high percentage of young birch in the Invermere Forest District where 62% of birch is under 20 years old; there is also a relatively high (36%) amount of aspen under 20 years old in that district.

- There is an unusually high proportion (57%) of birch in the 40-60 year age class in the Cranbrook Forest District, although birch has a relatively low overall abundance in that district.
- There is a very high representation (35-65%) of cottonwood in the 1-20 year age class in the Columbia Forest District and on TFL lands.

For research purposes, the regional age-class structure of aspen has generally been simplified to a few distinct classes. For example, the Westworth and Telfer (1993) study of summer and winter bird populations in Alberta aspen forests centred on four ages: 1-2 year clearcuts; and stands 14, 30, 60, and 80 years old. Pojar's (1995) study of bird communities in aspen forest of the Sub-Boreal Spruce Zone recognized four distinct age classes: clearcuts (under 7 years); sapling aspen (7-23 years); mature aspen (50-60 years); old aspen with trees 100 or more years old. Detailed accounts by Stelfox (1995) on relationships between stand age, stand structure, and biodiversity in Alberta aspen mixedwood forests, including the component studies on birds (Schieck and Nietfeld 1995), mammals (Roy et al. 1995), ungulates (Stelfox et al. 1995), bats (Crampton and Barclay 1995), flying squirrels (McDonald 1995), and vertebrates generally (Schieck and Roy 1995), focused on three aspen age classes: young (20-30 years); mature (50-65 years); and old (120 or more years).

Stands of short-lived species, such as aspen and birch, can contain a relatively broad range of age classes under certain circumstances. Some aspen stands in the United States Rocky Mountains have been documented to be multi-aged (Fetherolf 1917; Betters and Woods 1981; Jones and DeByle 1985). Oliver and Larson (1990) believed that uneven-aged aspen stands were relatively rare in North America but there are some documented western Canadian examples. These include the multi-aged aspen stand at Slave Lake, Alberta, shown in Figure 22 of Peterson and Peterson (1992) in which there is 18-year-old understory aspen beneath 120-year-old overstory aspen. The disturbance explanation for this example is not known but it is thought that canopy openings created by blowdown of old aspen, in the absence of nearby coniferous seed sources, allowed the younger aspen cohort to develop. Cumming et al. (2000) also provide examples whereby uneven-aged aspen stands can develop and persist through gap dynamic processes in 44-67 year old aspen stands of northeastern Alberta. Another example of multi-aged aspen stems in an individual stand occurs where competition-free circular aspen clones are expanding into grassland areas, many examples of which occur in the Cypress Hills of Alberta or the aspen parklands.

TABLE 4.1. Current age-class distribution of hardwoods in the Nelson Forest Region, excluding Boundary Forest District, computed from Section 3.7.0, Fraser and Davis (1996).

		Percent of area in each age class*		
Age class	Years	Aspen	Birch	Cottonwood
1	1-20	12.0	20.6	31.8
2	21-40	7.3	6.9	5.1
3	41-60	32.0	25.6	5.3
4	61-80	26.6	20.0	12.1
5	81-100	13.9	16.0	17.1
6	101-120	6.0	7.1	12.1
7	121-140	1.4	1.7	5.3
8	141-250	0.8	2.1	9.0
9	251+	0.0	0.0	2.2

* Area refers to “weighted net area” as defined in Fraser and Davis (1996). The latter authors presented age-class data separately for each Forest District and for TFL lands, but the values above are averages for the entire Nelson Forest Region, excluding Boundary Forest District.

5. HARDWOOD DISTRIBUTION IN RELATION TO BIOGEOCLIMATIC ZONES AND SOIL MOISTURE-SOIL NUTRIENT CLASSES

This section outlines the geographic distribution of biogeoclimatic subzones and variants in which aspen, birch, and cottonwood occur in the CBFWCP area. Stratification by biogeoclimatic zone is appropriate because distribution and habitat use of amphibians, reptiles, birds, and mammals in British Columbia is well documented by biogeoclimatic zone (Stevens 1995). Summaries in Tables 5.1, 5.2, and 5.3 list the site series that support these hardwood species in each subzone and variant, with the site series being indicative of the ranges of soil moisture and soil nutrient classes occupied by these species. Site series lists in Tables 5.1 and 5.2 are from Braumandl and Curran (1992), as are the place name descriptions of the geographic distribution of each subzone and variant within the Nelson Forest Region. Relative abundances of each hardwood species in each biogeoclimatic subzone-variant, based on volume compilations by Fraser and Davis (1996), are also included in the descriptions below and in Tables 5.1 and 5.2. Subzones or variants that support hardwoods in the Robson Valley Forest District (Table 5.3) are summarized from Meidinger et al. (1988).

This review did not evaluate the relevance for hardwoods of recent refinements to biogeoclimatic mapping in the Arrow and Columbia Forest Districts. Most of these refinements, a result of new digital mapping at 1:50,000, involve the ESSF Zone. However, some other recent changes described by Braumandl (2000) and the Southern Interior Forest Extension and Research Partnership (2001) for the Arrow and Columbia Forest Districts include:

- an increase of 61,000 ha in the area mapped as ICHvk1
- a decrease of 60,000 ha in the ICHmw2
- an increase of 39,000 ha in the ICHdw
- changes to mapping of natural disturbance types.

The Fraser and Davis (1996) stratification of hardwood volumes by subzones and variants, cited in several sections following, was based on 1:250,000 biogeoclimatic maps prepared prior to the recent amendments mentioned above.

5.1 Azonal Alluvial Ecosystems

Alluvial ecosystems that support cottonwood can occur as linear features in any of the forested biogeoclimatic zones of the CBFWCP area. Because such ecosystems are not limited to any one biogeoclimatic zone, they are recognized here as an azonal component of the regional forest vegetation. Although concentrated in alluvial ecosystems, cottonwood can also occur on upland sites. Examination of 1:250,000 maps of current forest cover distribution shows that many of the upland occurrences of cottonwoods are near riparian sites that support cottonwoods. Whether the locations of these upland cottonwoods are dependent upon nearby seed supplies from riparian cottonwoods is a topic requiring further study in southeastern British Columbia.

McLennan and Mamias (1992) summarized cottonwood's site relations as follows. Given the proper growing conditions, cottonwood is the fastest growing tree species in British Columbia. It thrives on nutrient-rich soils with fresh to very moist soil moisture regimes, and is poorly adapted to soil drought. Height growth is rapid on high benches of alluvial floodplains, although height growth decreases as bench height decreases and as flooding during the growing season increases. Cottonwood tolerates rooting zone flooding and waterlogged soil during the dormant season but prolonged flooding in the rooting zone during the growing season reduces productivity.

In their review of cottonwood in interior British Columbia, Simard and Vyse (1992) emphasized the following points. This species grows in a very wide range of climatic and edaphic conditions, another reason why it is characterized as azonal. It typically grows on riverbanks, gravel bars, and other lowland sites but can also occur on moist soils of upland sites. Overall, it has little tolerance for drought and survives in dry areas only where roots can reach a permanent moisture supply, often at the bases of slopes where there is seepage from upslope. Best growth of cottonwood occurs at low elevations on deep alluvial soils and the poorest growth is on freshly deposited gravel.

5.2 PP and IDF Zones in the Rocky Mountain Trench

The CBFWCP area of interest includes only the Kootenay Dry Hot Ponderosa Pine Variant (PPdh2) of the PP Zone. The other part of the PP Zone in the Nelson Forest Region, the PPdh1 Variant, which occurs further west in the Johnstone Creek-Boundary Falls-July Creek-Christina Lake area, is not considered here. The PPdh2 Variant occurs in the Rocky Mountain Trench between Skookumchuk Creek and the St. Mary River and between Baynes Lake and Tobacco Plains. In this variant, site series occupied by aspen or birch are identified in Table 5.1 and those in which cottonwood can occur are listed in Table 5.2. Data assembled by Fraser and Davis (1996) indicate that the PPdh2 Variant contains 6% of the cottonwood volume in the Nelson Forest Region, 1% of the aspen volume, and 0% of the birch volume. For these estimates, volume is calculated for all stems over 17.5 cm dbh, to a 10 cm top diameter, minus volume losses from decay, unavoidable waste, and breakage (see Tables 5.1 and 5.2). For each subzone and variant described below similar volume figures are given for each of aspen, birch, and cottonwood using data from Fraser and Davis (1996).

Also occurring in the Rocky Mountain Trench is the Kootenay Dry Mild Interior Douglas-fir Variant (IDFdm2). This variant occupies valley bottoms and lower slopes of the trench south of the Blaeberry River, and valley bottoms of major tributary valleys such as the Spillimacheen, Kootenay, Findlay, St. Mary, and Wigwam drainages. Site series on which aspen, birch, and cottonwood occur within this variant are identified in Tables 5.1 and 5.2. This variant contains 14% of the cottonwood volume, 9% of the aspen volume, and 2% of the birch volume in the Nelson Forest Region.

The portion of the IDF Zone that occurs within the Nelson Forest Region outside of the Rocky Mountain Trench (IDFdm1) was excluded because it is found mainly in the Kettle and Granby River drainages. Similarly, the IDFxh1 variant within the Nelson Forest Region was also excluded because it occurs mainly between Christina Lake and Grand Forks and in the Granby and Kettle drainages.

5.3 MS Zone Within Nelson Forest Region

The Dry Cool Montane Spruce Subzone (MSdk) occupies mid slopes in the Rocky Mountain Trench south of the Spillimacheen River, valley bottoms and lower slopes of valleys on the eastern flanks of the Purcell Mountains south of the Spillimacheen River, and valley bottoms and lower slopes in the Rocky Mountains south of the Kickinghorse River. Site series on which aspen, birch, and cottonwood occur within this subzone are identified in Tables 5.1 and 5.2. This subzone contains 10% of the aspen volume, 9% of the cottonwood volume, and 2% of the birch volume in the Nelson Forest Region.

The MSdm1 Variant is excluded from this review because its occurrence in the Nelson Forest Region is restricted to the Okanagan Highlands and the Midway Range that lies between the Granby and Kettle Rivers, locations that are west of the CBFWCP area of interest.

5.4 ICH Zone Within Nelson Forest Region

Eight subzones or variants of the ICH Zone were considered for this review. The site series on which aspen or birch occurs within each subzone or variant are identified in Table 5.1, and the same information is provided for cottonwood in Table 5.2. The geographic distribution of the eight subzones and variants within the CBFWCP area of interest, based on the location descriptions by Braumandl and Curran (1992), are as follows.

Some of the Dry Warm Interior Cedar-Hemlock Subzone (ICHdw) occurs west of the CBFWCP study area, but for purposes of this review the following areas of the subzone were considered: the valley along Lower Arrow Lake north to Fauquier; the Columbia River valley between Castlegar and the United States border; the Slocan Valley north to New Denver; the Kootenay Valley north to Kaslo; and along the Goat River and southern Moyie River valleys. The ICHdw subzone contains 24% of the birch volume, 14% of the aspen volume, and 11% of the cottonwood volume in the Nelson Forest Region.

The Kootenay Moist Cool Interior Cedar-Hemlock Variant (ICHmk1) occurs in: the Rocky Mountains along the Lower Bull, Lower Elk, Upper Kootenay, Beaverfoot, and Blaeberry rivers; the Rocky Mountain Trench between the Spillimacheen and Blaeberry rivers; and in the southern Purcell Mountains along the St. Mary, Moyie, and Yahk rivers. Occurrence of this variant along the Kettle and Granby drainages was not considered in this report. This variant contains 20% of the cottonwood volume, 15% of the aspen volume, and 3% of the birch volume in the Nelson Forest Region.

The Golden Moist Warm Interior Cedar-Hemlock Variant (ICHmw1) occurs at mid to lower elevations in the Rocky Mountains from the Kickinghorse River to the Sullivan

River, and in the northern Selkirk Mountains from Parson River to Gold River. This variant contains 12% of the aspen volume, 1% of the cottonwood volume, and 1% of the birch volume in the Nelson Forest Region.

The Columbia-Shuswap Moist Warm Interior Cedar-Hemlock Variant (ICHmw2) occurs in valley bottoms and on mid- to lower slopes along Upper Arrow Lake and Trout Lake, Lardeau River valley, and upper St. Mary River valley. It also occurs in mid-slope positions along Lower Arrow Lake, the Columbia River valley, Slocan Valley, Kootenay Valley, and along the Goat and southern Moyie River valleys. This variant contains 47% of the birch volume, 24% of the aspen volume, and 13% of the cottonwood volume in the Nelson Forest Region.

The Thompson Moist Warm Interior Cedar-Hemlock Variant (ICHmw3) occupies valley floors and lower slopes along Upper Arrow Lake from Galena Bay to Revelstoke. West of Revelstoke this variant occurs on warm slopes along the Trans Canada Highway and up side drainages of the Columbia River Valley such as Akolkolex River and Crawford, Drimmie, Cranberry, Blanket, and Begbie creeks. This variant contains 13% of the birch volume, 3% of the aspen volume, and 1% of the cottonwood volume in the Nelson Forest Region.

The Wells Gray Wet Cool Interior Cedar-Hemlock Variant (ICHwk1) is found from valley bottoms to mid slopes in the upper Duncan, Incomapleux, Akolkolex, Ilecillewaet, and Gold rivers, as well as along Revelstoke Reservoir north to the Goldstream River and along the Mica Reservoir north of Smith Creek. This variant contains 8% of the cottonwood volume, 7% of the birch volume, and 4% of the aspen volume in the Nelson Forest Region.

The Mica Very Wet Cool Interior Cedar-Hemlock Variant (ICHvk1) occupies valley bottoms and lower slopes in the northern Selkirk and Monashee Mountains, north of the Goldstream River to Mica Creek. This variant also occurs near the upper ends of Downie and Kirkup creeks and the Jordan, Wolsey, and Tangiers rivers. This variant contains 2% of the cottonwood volume, 0% of the birch volume, and 0% of the aspen volume in the Nelson Forest Region.

The Very Dry Warm Interior Cedar-Hemlock Subzone (ICHxw) barely extends into British Columbia from northeast Washington and northern Idaho from valley bottoms to mid slopes in the Pend d'Oreille River valley southeast of Trail, and on western and southern exposures and valley floors near the south end of Kootenay Lake from Boswell south to the vicinity of Rykerts at the international border. Although aspen and cottonwood are abundant in the ICHxw Subzone in the Creston area, Fraser and Davis (1996) indicated no commercial volume for any of aspen, birch, or cottonwood in this subzone.

5.5 ESSF Zone Within Nelson Forest Region

As indicated in Tables 5.1 and 5.2, the Silviculture Interpretations Working Group (1994) did not identify any site series in any of the ESSF subzones in which aspen, birch, or cottonwood are significant stand components nor are they considered species suitable for regeneration in any ESSF subzone. However, aspen does occur in the ESSF Zone. For example, the hardwood volume analysis by Fraser and Davis (1996) indicates that about 5% of the aspen volume in the Nelson Forest Region is from that zone, distributed as follows: 2% in the ESSFdk Subzone in the eastern Purcell Mountains south of the Spillimacheen River and in the Rocky Mountains south of the Kickinghorse River; 2% in the ESSFwm Subzone in the western Purcell Mountains and in the Rocky Mountains from the Cummins River to the Beaverfoot River, as well as along the Lower Elk River; and 1% in the ESSFwc4 Variant on upper slopes in the Monashee and Selkirk Mountains south of Revelstoke. The survey of forest greater than 140 years old in the Kootenay-Boundary Region (Quesnel and Leahy 1993) also lists aspen as a component species in the ESSFdk Subzone.

Fraser and Davis (1996) recorded no volumes of birch in any of the ESSF subzones or variants. There were no recorded volumes of cottonwood in the zone, except in the ESSFdk Variant (upper slopes of eastern Purcell Mountains) that supports 1% of cottonwood's total volume in the Nelson Forest Region.

5.6. SBS Zone Within Robson Valley Forest District

In the Robson Valley District current concentrations of hardwoods occur in two subzones of the Sub-Boreal Spruce Zone. In the district as a whole, the greatest distribution of hardwoods is in the SBSdh Subzone, with small areas of the undifferentiated SBSg Subzone also supporting hardwoods.

The SBS Zone is found in valley bottoms where there is cold air drainage. This zone generally occurs below the ICH Zone, except on the east side of the Rocky Mountain Trench between Horsey Creek and Dave Henry Creek where it extends directly up to the ESSF Zone. The SBSdh Subzone is found in the valley bottom of the Trench between Albreda and McBride, and the lower elevations of the northeast side of the Trench between Valemount and Dunster. The SBSdh is the driest subzone in the Robson Valley portion of the Rocky Mountain Trench. The primary reason for the relatively dry climate is the rain shadow of the Premier Range to the west. Climax stands of spruce and subalpine fire are relatively rare in this subzone because of the fire history of the area, and they occur as pure stands only on wetter sites or on relatively cool northeast aspects. As listed in Table 5.3, aspen, birch, and cottonwood are seral components of some site series in this subzone (Meidinger et al. 1988).

In the SBSdh Subzone portion of the Mount Robson Provincial Park area, B.A. Blackwell and Associates Ltd. et al. (2001), using Biophysical Habitat Units (BHU) rather than site series, highlighted hardwoods in one BHU that was called "Trembling aspen – red-osier dogwood moist lower slope (AD)". This aspen-dominated BHU occurs mainly at the base of colluvial slopes and on alluvial fans, with aspen dominating early seral stages and Engelmann spruce or subalpine fire growing through the hardwood canopy as stands age.

The undifferentiated SBSg Subzone is found in valley bottoms in the northwest part of the Robson Valley District between McBride and Dome Creek. The SBSg is wetter than the SBSdh Subzone.

5.7. ICH Zone Within Robson Valley Forest District

Two subdivisions of the ICH Zone (ICHmm and ICHwk3) support hardwoods in the Robson Valley District (Table 5.3). The ICHmm Subzone (formerly ICHj or ICHmc1) extends from near the southern end of Canoe Reach on Kinbasket Lake to just north of McBride. It is the driest and warmest of the ICH biogeoclimatic units in the Robson Valley area. Seral stands composed mostly of Douglas-fir, lodgepole pine, and aspen are more common in this variant of the ICH Zone than in any other part of the zone within the Robson Valley area for two possible reasons: the drier climate leads to dry forest fuel during the summer lightning season; and nay fires occurred during railroad construction early in the 20^{th} century. The main occurrences of hardwoods in the Robson Valley District are in this subzone and in the SBSdh Subzone. The ICHmm Subzone occurs not only on side slopes of the Trench above the SBSdh Subzone that occupies the valley bottom, but also in tributary valleys such as Castle Creek, Raush River, and Canoe River, where there are smaller concentrations of hardwoods than in the Trench (Meidinger et al. 1988).

In the ICHmm Subzone portion of the Mount Robson Provincial Park area, B.A. Blackwell and Associates Ltd. et al. (2001), using Biophysical Habitat Units (BHUs) rather than site series, highlighted hardwoods in one BHU that was called “Paper birch – red-osier dogwood moist lower slope (BD)”. This birch-dominated BHU typically occurs on moist sites where seepage from upslope provides abundant moisture throughout the growing season. Such sites are found at the bases of morainal and colluvial slopes and on alluvial fans.

The ICHwk3 Variant is found in the Rocky Mountain Trench from just north of McBride to near Dome Creek. The climate of this variant is more moist than the ICHmm Subzone. In the ICHwk3, seral stands are composed mainly of aspen; birch and Douglas-fir are less common seral species (Meidinger et al. 1988).

5.8. ESSF Zone Within Robson Valley Forest District

One subzone of the ESSF Zone (ESSFo) supports substantial aspen. The best example is the aspen on southwest-facing slopes of the upper Holmes River valley and in the Moose Lake-Red Pass area of the upper Fraser River valley. The ESSFo is one of the driest subzones in the Prince George Forest Region and wildfires are more common in this subzone than in the wetter ESSFb Subzone of the Robson Valley area (Meidinger et al. 1988). The relatively dry, fire-prone conditions probably explain the considerable occurrence of aspen in the ESSFo Subzone of the upper Holmes River valley.

5.9 Overview of Hardwood Occurrence in Relation to Soil Moisture and Soil Nutrient Classes

Relative frequencies of aspen, birch, and cottonwood in the climatic gradients represented by different biogeoclimatic zones, and their frequencies in various classes of soil moisture and soil nutrient gradients are diagrammatically summarized in Figure 5.9.1, based on silvical summaries by Klinka et al. (1990). All of British Columbia's main hardwood species are portrayed in Figure 5.9.1, and this figure also summarizes relative rankings of shade tolerance and potential of each species for natural regeneration in the shade and in the open.

A word interpretation of Figure 5.9.1 for the three hardwood species of the CBFWCP area can be summarized as follows:

- Aspen is rated as frequent in the ICH, IDF, MS, and ESSF Zones, and is less frequent in the PP Zone. It is very frequent in fresh and moist sites of the moisture gradient and on sites of rich or very rich nutrient status. Unlike cottonwood, aspen is also relatively frequent on dry sites of medium nutrient status. Aspen is generally rated as very shade intolerant and only infrequently as moderately shade tolerant. This species has low potential for natural regeneration in the shade and high potential for regeneration in the open.

- Birch is rated as frequent in the ICH and IDF Zones, and less frequent in the PP, MS, and ESSF Zones. It is very frequent on fresh sites of the moisture gradient, and on sites of medium or rich nutrient status. Unlike cottonwood, birch is relatively frequent on dry sites. Birch is less frequent than aspen or cottonwood on very rich sites. Like aspen, birch is very shade intolerant and is not rated by Klinka et al. (1990) as moderately shade tolerant under any site conditions. Birch has low potential for natural regeneration in the shade and high potential for regeneration in the open.

- Cottonwood is rated as frequent in only the ICH Zone of the CBFWCP area, but it does occur with less frequency in the IDF, PP, MS, and ESSF Zones. It is very frequent in moist sites of the moisture gradient and in sites that are very rich in nutrient status. It also occurs in fresh sites of the moisture gradient and rich nutrient sites but not as frequently as aspen or birch in these sites. Cottonwood is very shade intolerant and is of low potential for natural regeneration in the shade, with high potential for regeneration in the open.

Based on province-wide ecological information, generalized soil moisture/soil nutrient occurrences of aspen, birch, and cottonwood are graphically shown in Figure 5.9.2, derived from the most recent syntheses by Klinka et al. (2000). Sites where aspen is very frequent tend to be medium in soil moisture and soil nutrient status (see A1 in Figure 5.9.2). Sites with very frequent birch are somewhat moister than those where aspen is frequent, and sites with very frequent cottonwood are both more moist and more nutrient rich than sites with frequent aspen (see B1 and C1 in Figure 5.9.2). The total ranges of sites occupied by each hardwood species (including very frequent, frequent, and infrequent occurrences) are shown by graphs A2, B2, and C2 in Figure 5.9.2. Aspen can occur on the broadest range of soil nutrient classes (from very poor to very rich) and in a wide range of moisture classes except wet sites. Birch occurs on the broadest range of moisture classes but is generally absent on sites of very poor nutrient status. Even considering its places of infrequent occurrence, cottonwood has the narrowest total range of soil moisture classes of the three hardwood species (see graph C2 in Figure 5.9.2).

For each of the biogeoclimatic subzones and variants in the Nelson Forest Region, the ranges of soil moisture and soil nutrient classes for the site series in which aspen or birch are significant stand components are listed in Table 5.1. Similar information is shown for cottonwood in Table 5.2. For the Robson Valley Forest District, Table 5.3 shows the ranges of soil moisture and soil nutrient classes in subzones and variants where hardwoods occur.

It is instructive to compare Figure 5.9.2 with the relative abundances of aspen, birch, and cottonwood on good, medium, and poor sites, as summarized in Section 3.6.0 of Fraser and Davis (1996). The soil moisture/soil nutrient grids shown in Figure 5.9.2 indicate a gradient towards higher quality of site as one progresses from aspen to birch to cottonwood (see graphs A1, B1, and C1 in Figure 5.9.2 which indicate that very frequent occurrence of birch is on slightly wetter sites than aspen, and the most frequent occurrence of cottonwood is on even more moist and more rich sites). Table 5.9.1, based on site-class distribution data from Fraser and Davis (1996), shows these site quality differences on a regional basis. As expected, when averaged for the entire Nelson Forest Region (excluding Boundary Forest District), 26.7% of cottonwood occurs on good sites but only 18.1% of birch is on good sites and 15.5% of aspen occurs on good sites. At the opposite quadrant of the moisture-nutrient grid, 35.6% of birch occurs on poor sites, 31.3% of aspen occurs on poor sites, but only 13.9% of cottonwood occurs on poor sites (Table 5.9.1)

Aspen and birch are potentially present on a relatively wide range of site series in each biogeoclimatic subzone or variant. This prevents definitive statements about soil moisture or soil nutrient limitations to the distribution and abundance of aspen and birch. Based on information from Braumandl and Curran (1992), Table 5.1 summarizes the ranges of soil moisture classes and soil nutrient classes of site series in which aspen or birch is potentially significant stand components. Their potential to be a stand component is based on identification by the Silviculture Interpretations Working Group (1994) of site series where aspen or birch are capable of growing on the site and may be retained or encouraged to meet non-timber resource objectives such as biodiversity, wildlife habitat, or to manage root rot centres.

In Tables 5.1, 5.2, and 5.3, the following numbers identify soil moisture classes (0 – very xeric; 1 – xeric; 2 – subxeric; 3 – submesic; 4 – mesic; 5 – subhygric; 6 – hygric; 7 – subhydric) and nutrient classes by letters (A – very poor; B – poor; C – medium; D –

rich; E – very rich). Table 5.1 indicates that the site series that can have a significant presence of aspen or birch can range from very poor (A) to very rich (E) in soil nutrient regime, and from subxeric (0) to subhydric (7) in soil moisture regime. The main differences shown in Table 5.1 are as follows:

- In the ICH and MS Zones aspen and birch can occur in relatively dry site series, for example some that are listed as xeric (1); in the MSdm1 variant aspen may even be present in a site series that is classed as very xeric (Fd – Penstemon – Pinegrass).
- Site series that are classed as subxeric (2) can support aspen or birch in all of the subzones or variants of the ICH, MS, and IDF Zones.
- In the PP Zone aspen and birch occur only in site series that are classed as mesic (4), subhygric (5), or hygric (6).

Cottonwood does not occur over as wide a range of site series as aspen or birch. Table 5.2 indicates a relatively narrow range of site series in which cottonwood can be a significant stand component. As with aspen and birch, a broad range of soil nutrient classes (A to E) are represented by site series with significant cottonwood present. The strong association of cottonwood with site series in the mesic to very wet portions of the soil moisture regime (classes 4 to 7) is also portrayed in Table 5.2.

TABLE 5.1. Subzones and site series in the Nelson Forest Region where aspen or birch are significant stand components. This list is based on identification by Silviculture Interpretations Working Group (1994) of site series where hardwoods are capable of growing on the site and may be retained or encouraged to meet non-timber resource objectives such as biodiversity, wildlife habitat, or to manage root rot centres. Site series numbers and names are as defined in Braumandl and Curran (1992). The ranges of soil nutrient classes and soil moisture classes are from Braumandl and Curran (1992) for most subzones and variants, except for ICHmw3 and IDFxh1 where soil nutrient and moisture estimates are from Lloyd et al. (1990) for the Kamloops Forest Region. The percentage of each of aspen's and birch's total Nelson Forest Region volume that occurs in each subzone or variant is from summaries by Fraser and Davis (1996), in which gross volume is calculated for all stems over 17.5 cm dbh, to a 10 cm top diameter, less estimates for decay, unavoidable waste, and breakage.

ICH – INTERIOR CEDAR-HEMLOCK BIOGEOCLIMATIC ZONE

ICHdw (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6)[1]
This subzone contains 14% of the aspen volume and 24% of the birch volume in the Nelson Forest Region.

01a	CwFd[2] – Falsebox	aspen, birch
01b	CwFd – Falsebox	aspen, birch
02	FdPy – Oregon grape – Parsley fern	birch
03	CwHw – White pine – Devil's club	aspen, birch
04	CwHw – Devil's club – Lady fern	aspen, birch

ICHmk1 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 2 to 6)
This variant contains 15% of the aspen volume and 3% of the birch volume in the Nelson Forest Region.

01	CwSxw – Falsebox	aspen, birch
03	FdPl – Pinegrass – Twinflower	aspen
04	FdPl – Sitka alder - Pinegrass	aspen
05	SxwFd – Gooseberry – Sarsaparilla	aspen, birch
06	Sxw – Oak fern	aspen, birch
07	Sxw – Horsetail	aspen, birch

ICHmw1 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 1 to 6)
This variant contains 12% of the aspen volume and 1% of the birch volume in the Nelson Forest Region.

01	HwCw – Falsebox – Feathermoss	aspen, birch
02	Pl – Juniper – Twinflower	aspen, birch
03	HwCw – Falsebox – Pipecleaner moss	aspen, birch
04	CwFd – Soopolallie – Douglas maple	aspen, birch
05	CwHw – Devil's club – Lady fern	aspen, birch
06	CwHw – Oak-leaved blueberry – Oak fern	aspen, birch
07	CwHw – Horsetail	aspen, birch

[1] Soil nutrient regime (A - very poor; B - poor; C – medium; D – rich; E – very rich); soil moisture regime (0 – very xerix; 1 – xeric; 2 – subxeric; 3 – submesic; 4 – mesic; 5 – subhygric; 6 – hygric; 7 – subhydric).

[2] Tree species abbreviations: Act – black cottonwood; At – aspen; Cw – western redcedar; Fd – Douglas-fir; Hw – western hemlock; Lw – western larch; Pl – lodgepole pine; Py – ponderosa pine; Sx – unspecified spruce hybrid; Sxw – hybrid Engelmann – white spruce.

Table 5.1. Continued.

ICHmw2 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6)
This variant contains 24% of the aspen volume and 47% of the birch volume in the Nelson Forest Region.

01	HwCw – Falsebox – Feathermoss	aspen, birch
03	FdCw – Falsebox – Prince's pine	aspen, birch
04	CwFd – Falsebox	aspen, birch
05	CwHw – Oak fern – Foamflower	aspen, birch
06	CwHw – Devil's club – Lady fern	aspen, birch
07	CwHw – Horsetail	birch
08	CwSx – Skunk cabbage	aspen, birch

ICHmw3 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6)
This variant contains 3% of the aspen volume and 13% of the birch volume in the Nelson Forest Region.

01	HwCw – Falsebox - Feathermoss	aspen, birch
02	Fd – Juniper – Cladina	birch
03	FdPl – Pinegrass – Feathermoss	aspen, birch
04	CwFd – Soopolallie – Twinflower	aspen, birch
05	CwFd – Falsebox	aspen, birch
06	CwHw – Oak fern	aspen, birch
07	CwHw – Devil's club – Lady fern	aspen, birch
08	CwSxw – Skunk cabbage	aspen, birch

ICHvk1 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 2 to 6)
This variant contains 0% of the aspen volume and 0% of the birch volume in the Nelson Forest Region.

01	CwHw – Devil's club – Lady fern	aspen, birch
03	HwCw – Falsebox – Feathermoss	aspen, birch
04	CwHw – Oak fern – Spiny wood fern	aspen, birch
05	CwSxw – Devil's club – Horsetail	birch
06	CwSxw – Skunk cabbage	aspen, birch

ICHwk1 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6)
This variant contains 4% of the aspen volume and 7% of the birch volume in the Nelson Forest Region.

01	CwHw – Oak fern	aspen, birch
04	HwCw – Falsebox – Feathermoss	aspen, birch
05	CwHw – Devil's club – Lady fern	aspen, birch
07	Act – Dogwood - Twinberry	birch
08	CwSxw – Skunk cabbage	aspen, birch

ICHxw (Braumandl and Curran (1992) provided no soil nutrient or soil moisture data for this subzone.)
This variant contains 0% of the aspen volume and 0% of the birch volume in the Nelson Forest Region.

01	CwFd – Mock orange	aspen, birch

Table 5.1. Continued.

IDF – INTERIOR DOUGLAS-FIR BIOGEOCLIMATIC ZONE

IDFdm2 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 2 to 7) This variant contains 9% of the aspen volume and 2% of the birch volume in the Nelson Forest Region.

01	FdPl – Pinegrass –Twinflower	aspen
03	Fd – Snowberry – Balsamroot	aspen
04	FdLw – Spruce – Pinegrass	aspen, birch
05	SxwAt – Sarsaparilla	aspen, birch
07	Sxw – Horsetail	aspen, birch

MS - MONTANE SPRUCE BIOGEOCLIMATIC ZONE

MSdk (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6) This subzone contains 10% of the aspen volume and 2% of the birch volume in the Nelson Forest Region.

01	Sxw – Soopolallie – Grouseberry	aspen, birch
03	Pl – Juniper – Pinegrass	aspen, birch
04	Pl – Oregon grape – Pinegrass	aspen, birch
05	Sxw – Soopolallie – Snowberry	aspen, birch
06	Sxw – Dogwood – Horsetail	aspen

PP – PONDEROSA PINE BIOGEOCLIMATIC ZONE

PPdh2 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 4 to 6) This variant contains 1% of the aspen volume and 0% of the birch volume in the Nelson Forest Region.

03	PyAt – Rose – Solomon's seal	aspen, birch
04	Act – Dogwood – Nootka rose	birch

ESSF – ENGELMANN SPRUCE-SUBALPINE FIR BIOGEOCLIMATIC ZONE

No ESSF subzones or site series in which aspen or birch are identified by the Silviculture Interpretations Working Group (1994) as an acceptable species for non-timber objectives.

TABLE 5.2. Subzones and site series in the Nelson Forest Region where black cottonwood is a significant stand component. This list is based on identification by Silviculture Interpretations Working Group (1994) of site series where hardwoods are capable of growing on the site and may be retained or encouraged to meet non-timber resource objectives such as biodiversity, wildlife habitat, or to manage root rot centres. Site series numbers and names are as defined in Braumandl and Curran (1992). The ranges of soil nutrient classes and soil moisture classes are from Braumandl and Curran (1992) for most subzones and variants, except for ICHmw3 and IDFxh1 where soil nutrient and moisture estimates are from Lloyd et al. (1990) for the Kamloops Forest Region. The percentage of cottonwood's total Nelson Forest Region volume that occurs in each subzone or variant is from summaries by Fraser and Davis (1996), in which gross volume is calculated for all stems over 17.5 cm dbh, to a 10 cm top diameter, less estimates for decay, unavoidable waste, and breakage.

ICH – INTERIOR CEDAR-HEMLOCK BIOGEOCLIMATIC ZONE

ICHdw (Site series representing a range of soil nutrient classes from B to E and soil moisture classes 5 and 6)[3]
This subzone contains 11% of the cottonwood volume in the Nelson Forest Region.

03	CwHw[4] – White pine – Devil's club	cottonwood[5]
04	CwHw – Devil's club – Lady fern	cottonwood

ICHmk1 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 4 to 6)
This variant contains 20% of the cottonwood volume in the Nelson Forest Region.

05	SxwFd – Gooseberry – Sarsaparilla	cottonwood
06	Sxw – Oak fern	cottonwood
07	Sxw – Horsetail	cottonwood[3]

ICHmw1 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 4 to 6)
This variant contains 1% of the cottonwood volume in the Nelson Forest Region.

05	CwHw – Devil's club – Lady fern	cottonwood
06	CwHw – Oak-leaved blueberry – Oak fern	cottonwood
07	CwHw – Horsetail	cottonwood[3]

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[3] Soil nutrient regime (A - very poor; B - poor; C – medium; D – rich; E – very rich); soil moisture regime (0 – very xerix; 1 – xeric; 2 – subxeric; 3 – submesic; 4 – mesic; 5 – subhygric; 6 – hygric; 7 – subhydric).

[4] Tree species abbreviations: Act – black cottonwood; At – aspen; Cw – western redcedar; Fd – Douglas-fir; Hw – western hemlock; Py – ponderosa pine; Sx – unspecified spruce hybrid; Sxw – hybrid Engelmann – white spruce.

[5] For cottonwood in these site series, the Silviculture Interpretations Working Group (1994) suggested that hardwood management could be considered, if approved in management plans.

Table 5.2. Continued.

ICHmw2 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 4 to 7)
This variant contains 13% of the cottonwood volume in the Nelson Forest Region.

05	CwHw – Oak fern – Foamflower	cottonwood
06	CwHw – Devil's club – Lady fern	cottonwood[3]
07	CwHw – Horsetail	cottonwood[3]
08	CwSx – Skunk cabbage	cottonwood[3]

ICHmw3 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 4 to 6)
This variant contains 1% of the cottonwood volume in the Nelson Forest Region.

06	CwHw – Oak fern	cottonwood
07	CwHw – Devil's club – Lady fern	cottonwood[3]
08	CwSxw – Skunk cabbage	cottonwood[3]

ICHvk1 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 3 to 7)
This variant contains 2% of the cottonwood volume in the Nelson Forest Region.

01	CwHw – Devil's club – Lady fern	cottonwood
04	CwHw – Oak fern – Spiny wood fern	cottonwood
05	CwSxw – Devil's club - Horsetail	cottonwood[3]
06	CwSxw – Skunk cabbage	cottonwood[3]

ICHwk1 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 3 to 7)
This variant contains 8% of the cottonwood volume in the Nelson Forest Region.

01	CwHw – Oak fern	cottonwood
05	CwHw – Devil's club – Lady fern	cottonwood
06	CwSxw – Devil's club – Horsetail	cottonwood[3]
07	Act – Dogwood – Twinberry	cottonwood[3]
08	CwSxw – Skunk cabbage	cottonwood[3]

IDF – INTERIOR DOUGLAS-FIR BIOGEOCLIMATIC ZONE

IDFdm2 (Site series representing a range of soil nutrient classes from C to E and soil moisture classes from 5 to 7)
This variant contains 14% of the cottonwood volume in the Nelson Forest Region.

05	SxwAt – Sarsaparilla	cottonwood
07	Sxw – Horsetail	cottonwood[3]

MS - MONTANE SPRUCE BIOGEOCLIMATIC ZONE

MSdk (Site series representing a range of soil nutrient classes from B to E and soil moisture classes 5 and 6)
This subzone contains 9% of the cottonwood volume in the Nelson Forest Region.

05	Sxw – Soopolallie – Snowberry	cottonwood
06	Sxw – Dogwood – Horsetail	cottonwood

Table 5.2. Continued.

PP – PONDEROSA PINE BIOGEOCLIMATIC ZONE

PPdh2 (Site series representing a range of soil nutrient classes from B to E and soil moisture classes from 4 to 6)
This variant contains 6% of the cottonwood volume in the Nelson Forest Region.

03	PyAt – Rose – Solomon's seal	cottonwood
04	Act – Dogwood – Nootka rose	cottonwood[3]

ESSF – ENGELMANN SPRUCE-SUBALPINE FIR BIOGEOCLIMATIC ZONE

No ESSF subzones or site series in which cottonwood is identified by the Silviculture Interpretations Working Group (1994) as an acceptable species for non-timber objectives.

TABLE 5.3. Subzones, variants, and site series in the Robson Valley Forest District where aspen, birch, or cottonwood are significant stand components. This list is based on identification by Silviculture Interpretations Working Group (1994) of site series where hardwoods are capable of growing on the site and may be retained or encouraged to meet non-timber resource objectives such as biodiversity, wildlife habitat, or to manage root rot centres. Site series numbers and names are as defined in Silviculture Interpretations Working Group (1994), as modified from site series names listed by Meidinger et al. (1988). The ranges of soil nutrient classes and soil moisture classes are from Meidinger et al. (1988).

ICH – INTERIOR CEDAR-HEMLOCK BIOGEOCLIMATIC ZONE

ICHmm (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 6)[6]

O1	HwCw[7] – Spruce – Step moss	aspen, birch
02	CwSxw – Soopolallie	aspen, birch
03	HwCw – Step moss	aspen, birch
04	CwHw – Oak fern	aspen, birch, cottonwood
05	CWHw – Devil's club – Oak fern	aspen, birch, cottonwood
06	CwSxw – Devil's club – Horsetail	cottonwood

ICHwk3 (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 1 to 7)

01	CwHw – Oak fern	aspen, birch, cottonwood
03	CwSxw – Prince's pine – Cat's-tail moss	aspen, birch
04	HwCw – Step moss	aspen, birch
05	CwHw – Devil's club – Ladyfern	aspen, birch, cottonwood
06	CwSxw – Devil's club - Horsetail	aspen, birch, cottonwood
07	Hw – Wood horsetail - Sphagnum	aspen, birch, cottonwood
08	CwSxw – Skunk cabbage	cottonwood

SBS – SUB-BOREAL SPRUCE BIOGEOCLIMATIC ZONE

SBSdh (Site series representing a range of soil nutrient classes from A to E and soil moisture classes from 2 to 6)

01	SxwFd - Ricegrass	aspen, birch
03	FdPl – Pinegrass – Feathermoss	birch
04	Pl – Pinegrass - Feathermoss	aspen, birch
05	Pl – Labrador tea – Velvet-leaved blueberry	aspen
06	SxwFd - Thimbleberry	aspen, birch
07	Sxw – Horsetail	aspen, birch, cottonwood

ESSF – ENGELMANN SPRUCE-SUBALPINE FIR BIOGEOCLIMATIC ZONE

No ESSF subzones, variants, or site series in which aspen, birch, or cottonwood are identified by the Silviculture Interpretations Working Group (1994) as acceptable species for non-timber objectives.

6 Soil nutrient regime (A - very poor; B - poor; C – medium; D – rich; E – very rich); soil moisture regime (0 – very xerix; 1 – xeric; 2 – subxeric; 3 – submesic; 4 – mesic; 5 – subhygric; 6 – hygric; 7 – subhydric).

7 Tree species abbreviations: Cw – western redcedar; Fd – Douglas-fir; Hw - western hemlock; Pl – lodgepole pine; Sxw – hybrid Engelmann spruce - white spruce

TABLE 5.9.1 Distribution of aspen, birch, and cottonwood on each of three site classes in the Nelson Forest Region (excluding Boundary Forest District), computed from Section 3.6.0 of Fraser and Davis (1996).

Forest District	Percent of species area on each of three site classes*								
	Aspen			Birch			Cottonwood		
	Good	Medium	Poor	Good	Medium	Poor	Good	Medium	Poor
Arrow	18.1	54.0	27.9	34.5	44.6	20.9	32.0	58.6	9.3
Cranbrook	8.9	40.8	50.3	5.4	24.5	70.1	14.7	68.0	7.3
Golden	6.8	55.6	37.8	7.8	59.2	33.0	18.3	49.4	32.3
Revelstoke	34.3	56.8	8.9	21.0	59.8	19.3	45.2	50.8	4.0
Invermere	6.5	53.0	40.5	2.0	36.2	61.8	20.3	64.4	15.8
Kootenay Lake	11.0	55.2	33.8	32.7	40.5	26.8	8.3	76.2	15.5
TFL lands	23.2	56.8	19.9	23.2	57.6	19.2	48.4	48.4	3.3
Average	**15.5**	**53.2**	**31.3**	**18.1**	**46.1**	**35.6**	**26.7**	**59.4**	**13.9**

* Area refers to "weighted net area" as defined by Fraser and Davis (1996). Data are for the Nelson Forest Region except that the Boundary Forest District is excluded from the table above.

Species	Distribution along the climatic gradient (in the forested biogeoclimatic zones)										Distribution along the soil moisture gradient						Distribution along the soil nutrient gradient						Shade tolerance						Potential for natural regener-ation		Spatial requirements
	MH	ESSF & MS	BWBS	SBS	SBPS	IDF	ICH	PP	CDF	CWH	very dry	dry	fresh	moist	wet	ranking	very poor	poor	medium	rich	very rich	ranking	very shade-tolerant	shade-tolerant	moderately shade-tolerant	shade-intolerant	very shade-intolerant	ranking	in the shade	in the open	
Balsam poplar & black cottonwood	○	○	•	•	•	○	•	○	•	○		○	•	●	○	25			○	•	●	18				○	●	22	L	H	H
Trembling aspen		•	●	●	•	•	•	○	○	○	○	•	●	●	○	13		○	•	●	●	18			○	•	●	16	L	H	H
Red alder									•	●	○	•	●	●		22		○	•	●	●	18				○	●	18	L	H	H
Bigleaf maple						○			●	•			•	●	○	14			○	•	●	25			○	●	•	13	L	H	H
Paper birch		○	•	•	○	•	•	○	○	○	○	•	●	•	○	9		○	●	●	•	13				○	●	22	L	H	H

● very frequent   • frequent   ○ less frequent   □ absent

L low
M medium
H High

FIGURE 5.9.1. Frequencies of occurrence of native hardwood tree species in British Columbia in relation to biogeoclimatic zones, soil moisture/soil nutrient classes, and shade tolerance classes, based on rankings by Klinka et al. (1990) for 26 softwood and hardwood species in the province. The numerical rankings shown in the moisture gradient, nutrient gradient, and shade tolerance columns refer to the species' comparative position along gradients. A ranking of 1 would refer to a species adapted to the driest soils, nutrient poorest soils, or exhibiting the greatest shade tolerance; a ranking of 26 would apply to a species adapted to the wettest soils, nutrient richest soils, or exhibiting the least tolerance to shade.

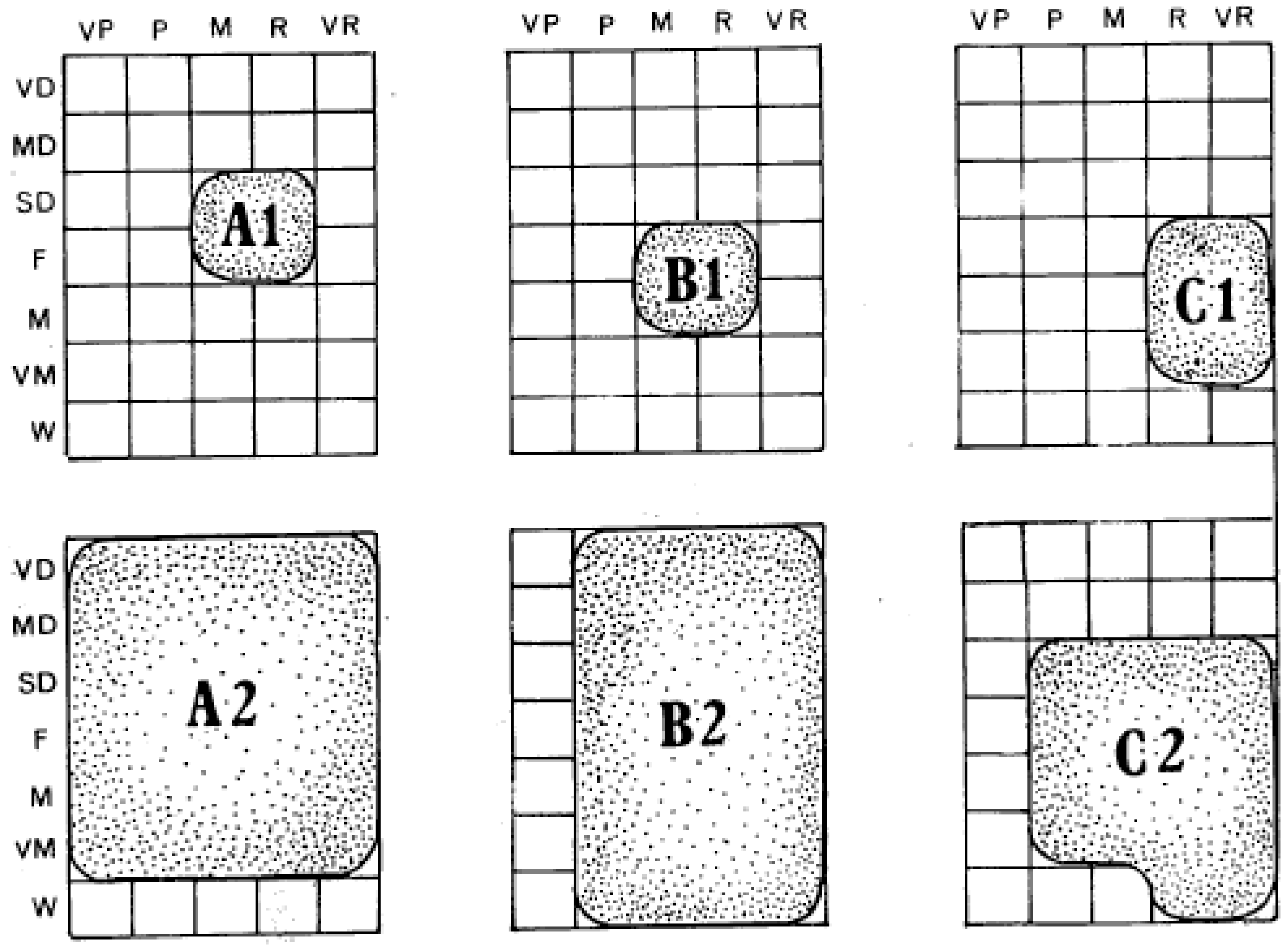

FIGURE 5.9.2. Generalized occurrences of aspen, birch, and cottonwood in relation to soil nutrient classes and soil moisture classes based on province-wide data by Klinka et al. (2000). Species identity: A – aspen; B – birch; C – cottonwood. Frequency classes: 1 – very frequent abundance; 2 – total range of occurrence including very frequent, frequent, and infrequent abundance. Soil nutrient classes: VP – very poor; P – poor; M – medium; R – rich; VR – very rich. Soil moisture classes: VD – very dry; MD – moderately dry; SD – slightly dry; F – fresh; M – moist; VM – very moist; W – wet.

6. NATURAL AND HUMAN-INDUCED DISTURBANCES

The reproductive strategies of aspen, birch, and cottonwood, indicate a strong relationship between landscape disturbance and distribution/abundance of these species. Therefore, a starting point for an overview of natural and human disturbances on hardwood abundance in the CBFWCP area is the current distribution of Landscape Units where aspen, birch, or cottonwood are now predominant. Current hardwood distributions based on forest cover data are described in Appendix III and in Section 4.3 of the main report.

6.1. Natural Disturbances

In the CBFWCP area aspen, birch, and cottonwood can be significant stand components in four of the five Natural Disturbance Types (NDTs) recognized by BCMOF and BCMOELP (1995). Hardwoods are not present in NDT 5 (alpine tundra and subalpine parkland) but the remaining four NDTs are represented by subzones or variants in which hardwoods may be significant stand components, as listed in Table 6.1.1.

Various reviews indicate that dominant natural forest disturbances in the Nelson Forest Region have included major fires in 1912 and 1948, mountain pine beetle at endemic levels throughout the period of record keeping, and widespread occurrence of Armillaria root disease and larch dwarf mistletoe (Steeger 1997). Mountain pine beetle and larch dwarf mistletoe do not directly impact hardwood species and are not outlined below. The main damaging agents for hardwoods today are summarized in Tables 6.1.2, 6.1.3, and 6.1.4.

6.1.1. Fire influences on hardwood stands

As reviewed in Section 3.1, fire is a dominant form of disturbance in the CBFWCP area. Ministry of Forests extension information about fire in dry forests of interior British Columbia does not specifically address present distributions and abundances of hardwoods in relation to current fire regimes (Daigle 1996). Also, interest in restoration of fire-maintained ecosystems in the East Kootenays (Egan 1998) has a conifer rather than a hardwood focus. Gayton (1996) described fire-related features of the Rocky Mountain Trench from the Montana border to Radium Hotsprings where historical and dendrochronological evidence shows that the area had a pre-contact fire frequency of 5-25 years. Similar fire history information summarized by Daigle (1996) demonstrates that fire suppression activities have increased the average fire return interval dramatically. Daigle’s examples, which included study sites at Canal Flats, Koocanusa Lake, and one other unspecified location in the east Kootenay region, indicate that where historical fire-return intervals were 7-20 years in the pre-contact period they are now 30-90 years. At present, restoration interests in the east Kootenay region are resulting in increased use of prescribed fire but this interest is directed mainly to restoration of grasslands rather than hardwoods.

In these dry forests, from an ecological standpoint the current area burned is too low to maintain fire-dependent ecosystems and stand structure that is resistant to intense crown fires. Because of the relatively low shade intolerance of hardwood species, it follows that hardwoods have a decreasing role in these fire-protected areas. Aside from the trend of favouring more shade-tolerant conifers, the reduced fire frequencies result in higher incidence of coniferous defoliators and bark beetles as well as increased tree mortality due to greater root contact between tree species vulnerable to root rot (Daigle 1996).

We emphasize the importance of the precautionary note by Huggard and Arsenault (1999) that natural disturbances based on estimates of fire return intervals are simply a guide. There are often significant differences between fire return intervals estimated indirectly from age distributions of current forest stands and fire return intervals defined by direct evidence of past fires. These differences in estimation of forest stand dynamics are relevant for those involved with hardwoods because regeneration of these species, especially aspen and birch, are so closely tied to fire history.

6.1.2. Insect and disease disturbances in hardwood stands

Aspen, birch, and cottonwood are host to an exceptionally large variety of insects and diseases (Ives and Wong 1988; Callan and Funk 1994; Callan and Ring 1994; Hiratsuka et al. 1995; Allen et al. 1996; Callan 1996; Pollard 1996; Callan 1998). However, these hardwoods are free of large stand replacement disturbances from insects or diseases such as the large areas of tree mortality created by bark beetles in conifers of interior British Columbia. One of the most conspicuous insect influences on hardwoods is forest tent caterpillar (*Malacosoma disstria*), but this defoliator does not result in stand replacement of hardwoods. The forest tent caterpillar particularly selects aspen and occurs over widespread areas of Canada. Although this caterpillar defoliates trees over large areas and can cause extensive growth losses, it generally does not result in mortality or have long-term impact on forest growth unless severe defoliation is prolonged or repeated defoliation is accompanied by severe drought (Canadian Council of Forest Ministers 2000). For the Nelson Forest Region and other forest regions in British Columbia, Allen (1998) provides historical data on forest tent caterpillar outbreaks. Large outbreaks of this insect are not common in the East Kootenay region.

Among the many hardwood diseases there are only two processes of regional ecological significance. First, the stem decay organisms that are much more prevalent in aspen, birch, and cottonwood than in their companion conifers are a major reason why these hardwoods are poorly represented in age classes greater than 120 years. Second, Armillaria and other root rots play a role in forest gap dynamics and in this context there are differences between hardwoods and conifers. Armillaria relations in stands that contain birch best demonstrate this. Recent work in British Columbia indicates that low densities of birch, when growing in intimate mixtures with Douglas-fir, may have positive effects by reducing stand mortality due to Armillaria root disease, maintaining long-term productivity, and enhancing stand diversity. The Armillaria Research Working Group of the Nelson Forest Region and the many investigators contributing to its objectives confirm the importance of this organism in forest ecosystems of the region

(Morrison et al. 1991; Morrison and Mallet 1996; Gerlach et al. 1997; Davis and Machmer 1998; DeLong et al. 2000b; Morrison 2000; Morrison et al. 2001). Armillaria is also being actively researched over a wider geographic area (McDonald et al. 1987; Shaw and Kile 1991).

TABLE 6.1.1. Natural Disturbance Types (NDTs) where hardwoods occur, stratified by biogeoclimatic subzones and variants in which hardwoods are significant stand components (see Table 5.1, 5.2, and 5.3), with generalized location of each subzone or variant within each NDT.

NDT	Biogeoclimatic units supporting aspen, birch, and cottonwood	Generalized location
NDT 1 (rare stand-initiating events)	ICHvk1	Valleys of northern Selkirk and Monashee Mountains
	ICHwk1	Valleys of Duncan, Incomapleux, Akolholex, Illecillewaet, and Gold rivers
	ICHwk3	In Trench of Robson Valley Forest District from just north of McBride to Dome Creek
NDT 2 (infrequent stand-initiating events)	ICHmw1	Lower elevations in Rocky Mountains from Kicking Horse R. to Sullivan R. and northern Selkirk Mountains from Parson R. to Gold R.
	ICHmw2	Valleys along Upper Arrow Lake and Trout Lake, and valleys of Lardeau and St. Mary rivers.
	ICHmm	In Trench of Robson Valley Forest District from Canoe Reach to just north of McBride
NDT 3 (frequent stand-initiating events)	ICHdw	Along Lower Arrow Lake, Columbia R. valley in Castlegar-Trail area, Slocan Valley north to New Denver, Kootenay Valley north to Kaslo, and along Goat and Moyie R. valleys
	ICHmk1	In Rocky Mountains along lower Bull, lower Elk, upper Kootenay, Beaverfoot, and Blaeberry rivers; in the Trench between Spillimacheen and Blaeberry rivers; and along St. Mary, Moyie, and Yahk rivers.
	ICHmw3	Valleys along Upper Arrow Lake from Galena Bay to Revelstoke, and in creek valleys west of Revelstoke
	MSdk	Mid-slopes of southern Trench, on eastern flanks of southern Purcell Mountains, and in Rocky Mountains south of Kickinghorse R.
	SBSdh	Valley bottom of Trench in Robson Valley Forest District between Albreda and McBride, with a wetter extension from McBride northwest to Dome Creek
NDT 4 (frequent stand-maintaining events)	ICHxw*	Along Pend d'Oreille R. southeast of Trail and near south end of Kootenay Lake
	IDFdm2	Valley bottom of Trench south of Blaeberrry R. and valley bottoms along Spillimacheen, Kootenay, Findlay, St. Mary, and Wigwam drainages
	PPdh2	Valley bottom of Trench between Skookumchuk Creek and St. Mary R., and between Baynes Lake and Tobacco Plains

* The Silviculture Interpretations Working Group (1994) recognized aspen and birch, but not cottonwood, as a significant stand component in the ICHxw Subzone. In all other subzones and variants all three hardwood species are potentially significant stand components.

TABLE 6.1.2. Aspen's main natural damaging agents (Klinka et al. 2000).

Damaging agent	Resistance class*	Comments
snow	M	high snowfall breaks branches rather than boles
wind	M	high winds break boles rather than uproot trees
Risk class		
fire	M	aspen can regenerate at fire intervals as short as 3 yr
insect	L	not a serious concern; defoliators (e.g., *Malacosoma* spp., *Choristoneura* spp.), wood-boring insects (poplar borer, *Agrilus* spp.), sucking insects (aphids, leafhoppers)
fungi	M – H	butt and root rots (e.g., aspen root rot), cankers (e.g., *Ceratocystis* spp. *Cytospora* spp.), leaf rust fungi (*Melamspora* spp.) and heart rots are a serious concern. Aspen and poplar leaf and twig blight are not a serious concern.
other agents	L	not a serious concern; browsing and bark-eating by mammals

* L – low; M – medium; H - high

TABLE 6.1.3. Birch's main damaging agents (Klinka et al. 2000)

Damaging agent	Resistance class	Comments
snow	L	high snowfall breaks branches rather than boles
wind	M	high winds break boles rather than uproot stems
Risk class		
fire	M	bark is highly flammable; fire frequency is lower in pure birch stands, higher in birch-conifer mixtures
insect	L	not a major concern
fungi	L	not a major concern

TABLE 6.1.4. Cottonwood's main damaging agents (Klinka et al. 2000).

Damaging agent	Resistance class*	Comments
snow	M	high snowfall breaks branches rather than boles
wind	M	high winds break boles rather than uproot trees
Risk class		
fire	L	fire risk in cottonwood stands is very low
insect	L	not a major concern
fungi	L	not a serious concern; heart rots (e.g., brown stringy trunk rot of hardwoods), leaf rust (*Melamspora* spp.)
other agents	L	not a major concern; browsing by large ungulates, root browsing and girdling by voles and mice

* L – low; M – medium; H - high

Tree species that are relatively resistant to Armillaria (aspen, birch, and cottonwood or balsam poplar) have a possible role for Armillaria control in sites where steepness of slope, soil characteristics, or other factors preclude stump removal of infected roots of Armillaria-susceptible conifers. There is evidence that root disease incidence is lower in birch-conifer mixtures than in pure stands of susceptible conifers. The degree to which birch is tolerant of Armillaria is uncertain, but some researchers suggest that it can be susceptible. One concern is that, in locations where Armillaria is present, cutting birch can make matters worse by stimulating Armillaria development. However, the ecological importance of birch in overall maintenance of the forest ecosystem health is recognized, particularly on sites where root diseases are a problem for conifers.

Armillaria has been characterized as a major impediment to sustainable management of forest ecosystems in southern British Columbia (Morrison 2000; Morrison et al. 2001). Armillaria fungi are intricately linked to several ecosystem processes such as nutrient cycling, successional changes, and biodiversity, some of which involve birch as a pioneer hardwood species. Armillaria root disease provides dead, dying, and decayed trees for use by wildlife species. Canopy gaps created by Armillaria induced conifer mortality are often invaded by birch and aspen, and such stand openings have important habitat value for several wildlife species (Steeger and Machmer 1995; Steeger and McLeod 1996; Steeger et al. 1996; Martin 2000b).

In the Kamloops and Nelson Forest Regions, birch is often considered a serious long-term competitor for conifers, although it is debatable whether the competition is as serious as some managers perceive. Vigorous and abundant birch can cause localized threats to the survival and growth of intolerant species, such as western larch and lodgepole pine, and moderately shade tolerant species, such as Douglas-fir and spruce. In the ICH Zone of the Kamloops Forest Region, birch is not a problem for regeneration establishment but may affect growth of conifers within the first 15 years after conifers are established (Simard 1996a, 1996b).

6.1.3. Periodic flooding disturbances

Excellent summaries exist on the life history and ecology of riparian cottonwoods in western North America (Rood and Mahoney 1991a; Bunnell and Dupuis 1993; McLennan 1993a, 1993b; Braatne et al. 1996; Law et al. 2000). These reviews defined fundamental ecological relationships between riparian cottonwoods and the alluvial floodplains they inhabit. Information more specific to cottonwood in British Columbia is found in Fyles and Bell (1986), McLennan and Mamias (1992), Simard and Vyse (1992), and Peterson et al. (1996).

In general, plant succession on river terraces of southeastern British Columbia is directed to a vegetation type dominated by cottonwood and spruces. The cottonwood-dominated successional stage can develop from either a dry gravel community type or a shallow sand community type (Fyles and Bell 1986). Flood disturbances can disrupt these successional phases at any stage of their development.

With regulatory and other reasons for limiting forest harvesting in riparian and alluvial ecosystems, and with aggressive suppression of fires, an important management question is whether periodic flood events will provide sufficient disturbance for long-term maintenance of cottonwoods in flood-prone areas. There are also other management questions. If western redcedar and valley-bottom spruce gradually gain in abundance in alluvial ecosystems, as a result of reduced disturbance from fire or harvesting, will there be a long-term need to harvest alluvial conifers to sustain hardwood stands there? This is a question needing further research.

Rood and Mahoney (1991b) summarized the importance and extent of cottonwood forest decline downstream from dams, based on observations of *Populus balsamifera, Populus fremontii,* and *Populus deltoides* from studies mainly east of the Rocky Mountains plus some in California. Many of the physical processes and tree-growth responses they described could apply to southeastern British Columbia. The distributions of riparian cottonwoods shown on 1:250,000 maps for the Nelson Forest Region were not analyzed in detail for this review but this mapped information could help to define influences of altered flow regimes on present locations of cottonwood stands.

6.2. Human-Induced Disturbances

The subsections below do not go into detail, but simply highlight the three main human-induced disturbances that influence distribution and abundance of hardwoods in southeastern British Columbia – private-land activities, forest harvesting-silvicultural influences, and domestic livestock influences. Recent analysts have made it clear that disturbance-related forest management issues in south interior British Columbia involve complex subjects requiring interdisciplinary research approaches (Klenner and Vyse 1999).

6.2.1. Private land development influences

Analyses by Fraser and Davis (1996) indicated that, within the Nelson Forest Region, Landscape Units that contained the greatest concentrations of hardwoods on private lands were located in the Revelstoke, Golden, and Fernie areas. It was beyond the scope of this review to document the stand-initiating disturbances in these areas where hardwoods are now prominent. However, a general knowledge of the history of land settlement and subsequent land-use patterns in these areas suggests land clearing as a significant stimulus for hardwood establishment in the past 100 years. Although not documented, there is reason to hypothesize that aspen could have established by seedlings on land newly disturbed by private land occupation, just as this species has established on banks adjacent to highways in the Revelstoke-Golden area.

6.2.2. Forest harvesting and silvicultural influences

Until there are pulp or oriented strandboard plants in southeastern British Columbia that would draw on hardwood raw material, birch remains the main hardwood of commercial interest in the foreseeable future. The analysis by Fraser and Davis (1996) recognized this current focus on birch. The web site for the Salmo Log Yard (www.logsale.com) does not presently indicate any significant trade in hardwood raw material.

This review recognized the diversity of successional paths that can follow different forest harvesting patterns or different silvicultural practices. However, this is a complex and dynamic subject too detailed to summarize meaningfully in this review. This is the subject of much of the recent and current research of the B.C. Ministry of Forests. It is assumed that harvest of conifers will be the main regional source of land disturbances in the foreseeable future, especially in the ICH Zone where the largest volumes of hardwoods occur. This suggests that Ministry of Forests policy, practices, and research will provide much of the information desired by the CBFWCP regarding influences of forest practices on abundance, distribution, and age-class structure of future hardwood stands.

The detailed literature review by Rogers (1996) on disturbance ecology in relation to forest management makes it clear that there is a recent shift in viewpoints about disturbances in the forest landscape. In the past, most forest and land managers viewed disturbance negatively but recently the opposite viewpoint has come to prevail. Rogers emphasizes that many managers now believe that preservation or emulation of natural disturbance regimes is essential to promote healthy, dynamic ecosystems. Attempts to emulate natural disturbances are being tested not only for silvicultural and wildlife habitat reasons but also for other ecosystem management objectives, such as invertebrate biodiversity (Spence et al. 1999).

There is continuing research on how well emulation attempts can truly imitate natural disturbance. In British Columbia, work by DeLong (1996) to manage patterns of forest harvest based on natural fire disturbance patterns is an example of the new emphasis described by Rogers (1996). This emphasis is recognized in the Forest Practices Code of British Columbia *Biodiversity Guidebook* (BCMOF and BCMOELP 1995) that focuses on management to encourage various seral stages based on natural disturbance types that occur in different biogeoclimatic subzones and variants.

Simard and Hannan (2000) indicated that brushing treatments to control young birch that is overtopping conifers are widespread in the ICH and IDF Zones of southern British Columbia, although total land areas receiving such treatment were not specified. Broadcast treatments, where all of the birch is cut or sprayed, have been favoured to keep brushing costs low (Simard and Hannam 2000). Some unwanted side effects of broadcast birch treatments include decreased stand structural diversity, increased Armillaria root disease incidence, and increased pest damage (Simard and Heineman 1996). The researchers indicated that more research is needed on competition indices and thresholds for a broader range of target species, vegetation complexes, sites, and stand ages. Studies are also required to identify the impacts of selective versus broadcast birch treatments on overall growth and yield of stands, rotation length, wood quality, biodiversity, and wildlife habitat. Other research (Vyse 1996; Wang et al. 2000) confirms the value of leaving a birch canopy as a nurse crop for understory conifers in mixed birch-conifer stands.

6.2.3. Domestic livestock influences

In descending order of importance, the ten most negative impacts on riparian cottonwood ecosystems in western North America were listed by Braatne et al. (1996) as follows: livestock grazing; water diversion; domestic settlement; exotic plants; on-stream reservoirs; channelization; agricultural clearing; gravel mining; direct harvesting; and beavers. A key reason why livestock grazing tops this list is that browsing and trampling of seedlings and sprouts impacts the vulnerable regeneration phase of cottonwood thereby threatening the sustainability of this species.

Some of the more detailed reviews of the ecological costs of livestock grazing in western North America (Kauffman and Krueger 1984; Fleischner 1994; Erwin et al. 1994; Powell et al. 2000) do not provide information specifically for the hardwood species dominant in the CBFWCP area. Case and Kauffman (1997) is one example that does provide data on recovery of cottonwood after cessation of cattle grazing. Their study in the Blue Mountains of northeast Oregon confirmed earlier work by Green and Kauffman (1995) that indicated rapid recovery of cottonwood growth soon after cattle and wild ungulate use was reduced in riparian areas.

Most of the experience with aspen responses to livestock grazing is from the aspen parkland zone of the prairie provinces and the United States Rocky Mountain region (DeByle 1985; Mueggler 1985; Bailey and Arthur 1985; Bailey et al. 1990, Hudson and Blythe 1986). This means that much of the available information is derived from areas where aspen tends to occur in groves instead of continuous stands. Range managers have used the health of aspen groves as a monitor (Greenway 1990). In particular, the presence or absence of aspen sucker reproduction has been used as an indicator of range condition. If aspen suckers are present, range is considered to be in good condition; if absent, range condition is thought to be unsatisfactory (Houston 1954). Further north, where aspen tends to occur in larger continuous stands, the effects of grazing by domestic livestock may be different. For example, near Rochester, Alberta, Weatherill and Keith (1969) found that aspen was not influenced significantly by grazing. There was no significant difference in aspen communities sampled for three levels of grazing intensity (ungrazed, light, and heavy grazing). In the Rochester area, as grazing intensity by domestic livestock increased, there were indications that light grazing was beneficial to ruffed grouse and that heavy grazing was harmful. An adverse impact of grazing on snowshoe hare populations was readily apparent. The factor most likely limiting hares in grazed aspen woodlands was thought to be a lack of suitable summer cover due to the decrease of tall herbaceous cover.

Aspen-cattle relationships have been the subject of considerable trials in northeastern British Columbia where work by Hays and others, reported by the Hardwood/Mixedwood Steering Committee (Robinson 1993), confirmed that aspen stocking can be very high in hardwood cutblocks and that such dense aspen sucker stands can inhibit cattle access, leading to underutilization of available forage.

The work by Telfer (1994) on cattle and cervid interactions in southwestern Alberta dealt with habitats that contained aspen and balsam poplar, but the data collection focused on ungulate removal of understory forage during winter rather than on cattle as a disturbance factor in aspen-dominated stands. Telfer's data indicated that cattle food intake was still predominantly herbaceous in winter (88.6%) with only 6.8% of the winter intake coming from browsing of aspen, balsam poplar, or saskatoon.

7. OVERVIEW OF HARDWOOD ROLE IN ECOLOGY OF MIXED STANDS

As summarized by Massie et al. (1994), hardwoods serve several important ecological roles. They are commonly viewed as a nurse crop for other commercially important species. They have nutrient cycling characteristics that are different from conifers. Although not well documented, hardwoods are thought to exert different microclimatic and hydrologic influences than do conifers. Hardwoods are prominent early colonizers of disturbed areas and in this context they provide rapid carbon fixation in their period of fast juvenile growth. At the other end of their life cycle, hardwoods have a relatively early release of carbon because most stands break up at younger ages than coniferous stands. Hardwoods are relatively resistant to airborne pollutants because they carry a receptive surface area of foliage for only part of each year. Several hardwood species are important for stabilization of soil erosion and protection of aquatic habitats in alluvial and riparian ecosystems. Hardwood dominated ecosystems are also important contributors to the overall genetic and biological diversity of regional forests. This synopsis of hardwood roles in ecological processes reported by Massie et al. (1994) applies to aspen, birch, and cottonwood in the CBFWCP area. Some specific examples of these key ecological roles of hardwoods are given below.

- **Hardwoods as nurse crops –** Shepperd and Jones (1985) defined a nurse crop as any stand of trees or shrubs that fosters development of another species, usually by protection from frost, sunscald, very high temperatures, or wind. Each of aspen, birch, and cottonwood has been described as nurse crops by various investigators. Aspen is referred to as a nurse crop because of the shade it provides to coniferous tree species that are not easily established in full sunlight. Kabzems and Lousier (1992) investigated aspen's role in white spruce germination and seedling establishment in the Fort Nelson area. The description by Ebata (1989) of pest concerns during backlog reforestation in British Columbia provides another example of aspen's role as a nurse crop. Root rots are a concern for spruce regeneration, but sites that contain pure aspen generally do not require treatment for *Tomentosus* root rot because aspen is not a known host. Birch appears to have a similar nurse crop role. Simard (1990) indicated that the retention of a low density of birch can reduce the spread of Armillaria root rot in Douglas-fir stands of Interior British Columbia. Other investigators have suggested that birch provides nurse crop functions by improving soils through enhanced nutrient cycling, by protecting conifers from frost, and by increasing the wind-firmness of stands on shallow soils (Perala and Alm 1989). For cottonwood, McLennan and Klinka (1990) described an approach for coastal areas that uses a nurse tree regeneration method where the shading of black cottonwood saplings suppresses the vigor of shade-intolerant shrubs, thus providing improved growing conditions for shade-tolerant conifers such as western redcedar.

- **Nutrient cycling and maintenance of site productivity –** Aspen's most important nutrient-related features were summarized by Peterson and Peterson (1995) as follows:
  - on the same site aspen leaves have higher nutrient content than conifer needles, suggesting that aspen functions as a nutrient pump;
  - aspen is adapted for rapid growth and high nutrient uptake early in stand development;
  - carbohydrates are stored belowground in long-lived clonal root systems of aspen and the roots have high nutrient uptake rates;
  - with its high nitrogen requirements, aspen is very sensitive to nitrogen supply;
  - forest floor decomposition and nutrient turnover are more rapid under aspen than under spruce;
  - more biomass and litterfall is present in understory vegetation below aspen than under conifers;
  - overall, aspen retains nutrients effectively within the ecosystem;

  For birch, Simard and Vyse (1992) emphasized that hardwoods have a positive effect on soil development. This is relevant because a common practice in the southern Interior is to remove or reduce hardwoods to encourage free-growing conifers. The effects of such practices on nutrient capital of forest soils are not well known, although nutrient relations of hardwood species is now an active area of research (Brown 1999), including studies of nutrient aspects of hardwood litter under aspen (Prescott et al. 2000a, 2000b; Prescott and Blevins 2000), and birch (Thomas and Prescott 2000).

  Birch and other hardwoods are usually harvested by whole-tree skidding, leading to a concern for nutrient losses if hardwoods were managed on short rotations of less than 60 years with much of the foliage and branch biomass removed from the harvest site. In the ICHmw3 Variant, Wang et al. (1996) found that as birch stand age increased an increasing proportion of annual biomass increment was allocated to stems but nutrients were preferentially accumulated in birch leaves. Overall nutrient content of aboveground birch biomass increased with stand age but average rates of nutrient accumulation in biomass were greatest in the early stages of stand development and less marked as stands aged.

  For cottonwood, Krajina et al. (1982) emphasized that this species has very high nutritional requirements, particularly for calcium, magnesium, and nitrogen. The major sources of nitrogen are nitrates available in base-rich alluvial soils. Subsequently van der Kamp (1986) determined that nitrogen fixation occurs in the wetwood of the upper bole of cottonwood stems. This is an important finding because it identifies a process through which cottonwood plays a significant role in fixation and cycling of nitrogen within alluvial ecosystems.

- **Influences on microclimatic and hydrologic relationships** - The fact that hardwoods lose all of their foliage annually determines the hydrological properties of hardwood stands more than any other factor. Both leaf area index and seasonal duration of leaf retention in hardwood forests are about half the values of those in coniferous forests. Interception losses in conifers range from 20-85% of total precipitation and from 10-50% in hardwoods when their leaves are out (Hinckley et al. 1981). Canopy water storage capacities in winter are much lower in hardwood stands than in conifers. Aspen forests are thought to allow more groundwater recharge than conifer forests, primarily because of lower seasonal water loss to interception by aspen as compared to conifers (Perala and Russell 1983; Gifford et al. 1984; Perala 1990b, 1990c).

- **Colonizers of disturbed sites through rapid natural regeneration –** All of the hardwood species of the CBFWCP area have the potential to rapidly invade large disturbed areas. This is strategically important because rapid re-greening of harvested areas is important to the public who consider recently logged areas aesthetically displeasing. Although not well quantified for different ecosystems in British Columbia, the rapid reestablishment of a woody plant cover after forest harvesting and other disturbances probably reduces precipitation-induced soil erosion. Also, the rapid establishment of hardwood regeneration after harvesting creates new and different wildlife habitat more quickly than would happen with coniferous regeneration, through early creation of vertical structure and an early abundance of browse and forage species (Massie et al. 1994).

- **Hardwood influences on carbon budgets –** In relation to the Kyoto protocol, there is now general interest in the role of forests as carbon sinks. There are two important features of hardwoods in this context. The first feature is that hardwoods commonly have exceptionally rapid growth rates in the first one or two decades of stand development. In the early years of stand development, species such as aspen, birch, or cottonwood are very effective at capturing atmospheric CO_2. Data from the prairie provinces indicate that within ten years from the date of stand establishment hardwood tree species that characteristically occupy disturbed sites can achieve standing crop densities (dry weight of aboveground standing crop per cubic metre of stand space) at least equal to those of mature forest stands (Peterson et al. 1982). The second important feature is that they do not have long life spans when compared with conifer tree species. Carbon stored in hardwoods is not a very secure reservoir because respiratory losses associated with decaying wood, whether in standing trees or in stems lying on the ground, result in a significant release of carbon long before hardwood stands reach the ages typical of old-growth coniferous stands. These two characteristics – rapid carbon fixation in the early phase of stand development and relatively early release of carbon with hardwood stand breakup often as early as 100 years old – must be considered when estimating the relative merits of hardwoods and softwoods for forest carbon sinks.

- **Recipients of airborne pollutants –** Massie et al. (1994) mentioned that the abundance of hardwood tree species and shrubs in a substantial radius around Trail, B.C. This suggests that hardwoods may be better adapted than conifers to cumulative effects of past air pollution from smelting facilities. This is a subject of continuing investigation and monitoring. Some investigators have indicated that hardwood species are more resistant to atmospheric pollutants because they do not have exposed foliage for the entire year. However, the relationship may not be that simple. For example, some studies (Addison et al. 1984) indicate that hardwood trees and shrubs are more sensitive than conifers possibly because CO_2 can enter broadleaves more easily than needles.

- **Soil stabilizers on new soil surfaces in alluvial and other habitats** – As early-succession species, aspen, birch, and cottonwood are frequent pioneers on freshly exposed habitats. The rapid establishment of a soil-stabilizing root system by cottonwood seedlings on alluvial sites is widely documented (Fyles and Bell 1986; DeBell 1990; Braatne et al. 1996; Rood and Mahoney 1991a and 1991b). On upland sites birch is also known to be a rapid colonizer of sites such as colluvial slopes (see Figure 34 in Peterson et al. 1997). The soil stabilization role of aspen is less clear than for birch, except in those circumstances where seedling establishment of aspen has been documented.

- **Contributors to biological diversity of British Columbia's forests –** Forest harvesting guidelines to enhance biodiversity typically include provisions such as: retention of snags and green trees; regeneration of stands with a mixture of tree species; retention of a hardwood component during vegetation management; and promotion of mixed species stands including a hardwood component during spacing and thinning operations (Klenner and Kremsater 1993; Kremsater and Dupuis 1997). Aspen, birch, and cottonwood clearly have an important role in fulfilling these guidelines.

7.1. Some Key Ecological Differences Between Hardwoods and Conifers

Key differences between aspen and conifers are highlighted in Table 7.1. A comparable table outlining differences between cottonwood and associated conifers has also been published (Peterson et al. 1996) but is not reproduced here because the aspen information (Table 7.1) is representative of cottonwood as well. A similar table distinguishing birch from conifers is reproduced in Table 7.2. An overview comparing some silvical and silvicultural features of aspen, birch, and cottonwood appears in Table 7.3.

TABLE 7.1. Some key silvical differences between aspen and conifers (Peterson and Peterson 1995).

1. Unlike conifers, aspen grows in clones made up of many genetically identical stems per clone.
2. Aspen's suckering provides more rapid natural regeneration of disturbed sites than is possible with conifers.
3. During stand development, aspen is better than conifers at regulating its density through self-thinning.
4. Aspen's shorter life span and lower age of maturity, relative to conifers, makes aspen a more likely candidate for short-rotation management; the shorter natural life span also allows aspen stands to progress more quickly than conifers through structural changes that are important for wildlife; natural production of snags, cavity-nesting opportunities, and creation of decay-laden foraging sites in branches and stemwood all occur earlier in aspen than in conifer stands.
5. Aspen, like several other hardwood species, has a higher rate of photosynthesis per unit foliage of biomass than conifers.
6. Unlike conifers, aspen is a very effective capturer of carbon during rapid growth in its first 20 years of stand development, before there is a conifer overstory; this high rate of carbon fixation in early aspen stand development is balanced by high rates of carbon release between 100 and 150 years during aspen stand breakup, a carbon release period that occurs earlier than in conifer stands.
7. Aspen's bark is more susceptible to physical damage than conifers, a factor contributing to greater susceptibility to stem decay than in conifers.
8. Despite aspen's greater susceptibility to stem decay, it is less susceptible to root diseases than conifers, especially *Armillaria*.
9. Aspen can be a nurse crop for conifers, but the opposite does not occur.
10. Aspen has higher nitrogen concentrations in twigs and branches than conifers, a feature of importance to some species of wildlife; aspen also accumulates larger amounts of Ca than conifers.
11. Aspen foliage has higher N, lower lignin, and lower lignin:N and C:N ratios than conifers.
12. Overall, aspen ecosystems have more rapid turnover of nutrients than conifer ecosystems.
13. Aspen forests allow more groundwater recharge than conifer forests by intercepting less water, but aspen also depletes soil water faster and to greater depth than conifers.
14. Aspen stands typically have a greater diversity of understory shrub and herb species, and therefore sometimes greater biodiversity and wildlife habitat values, than conifer stands.
15. Aspen, with other hardwoods, influences wildlife habitat more rapidly than conifers do because the rapid early hardwood growth results in early creation of vertical structure, and an early abundance of biomass of browse and forage value.

TABLE 7.2. Some biological features of birch that distinguish it from conifers or other British Columbia broadleaf species based on Peterson et al. (1997).

- Birch is immune to several root diseases (*Phellinus weirii*, *Inonotus tomentosus*, *Heterobasidion annosum* and *Loptographicum wageneri)* and has low susceptibility to *Armillaria ostoyae*. Birch can be planted on diseased sites to hold the effects of *Phellinus weirii* within acceptable limits provided sites are suitable for birch. On sites infected with *Armillaria* or *Phellinus*, root disease spread may be reduced where birch is regenerated in mixture with susceptible conifers, although mortality among susceptible species can be expected.

- Birch stems decay differently than stems of most of birch's companion tree species that lose their bark quickly; in contrast, bark is the last part of the stem to decay in birch. Intact cylinders of bark often remain long after the wood of downed birch stems has decayed, possibly because the bark is effective in keeping the water content of decaying wood high, thus promoting decomposition of the downed stem wood.

- Birch contains more total foliar and branch nutrients than conifers, a factor that makes birch foliage biomass a very important part of nutrient cycles. This is especially true as birch foliage decomposes much faster than wood or bark, and because of the relatively high proportion of birch's aboveground nutrients contained in the foliage; in birch, the biomass of small roots (< 1 mm diameter) may be twice that of conifers, suggesting that birch can provide intense root competition to companion tree species.

- Unlike conifers, many birch are multi-stemmed. This adds to birch's aesthetic appeal and coppice ability but is not conducive to good stem production.

- Of the four main broadleaf species in British Columbia, birch is the least demanding in terms of soil nutrients and is the best adapted to soil drought.

- Birch does not exhibit the extremely rapid early growth characteristic of broadleaf species such as alder and black cottonwood but early growth of birch is still faster than that in conifer species.

- Birch does not reproduce well in established forests; once companion conifers are present in the late stages of forest succession, subsequent development of birch is highly dependent on disturbances that create gaps in the conifer or mixedwood canopy.

- Stand break-up in birch occurs earlier than in conifers; stand deterioration in birch typically occurs between 75 and 100 years when tops start to die, leaving an uneven upper canopy; in the Lake States, many examples of widespread birch mortality are thought to be triggered by periods of drought, compounded by borer and leaf miner attacks.

TABLE 7.3. Some silvical and silvicultural comparisons of the main hardwood species in British Columbia., based on Peterson et al. (1997). Symbols: *** = predominant feature for the species; ** = applies to the species but not predominately so; * = does not apply to the species; ? = silvical or silvicultural aspects not well known.

Feature	Aspen	Birch	Cottonwood	Red alder
• vegetative reproduction almost exclusively by root suckers	***	*	**	*
• vegetative reproduction common from stump sprouts	**	***	***	**
• vegetative reproduction common from broken branch or stem segments	*	*	***	*
• readily reproduced by stem or root cuttings	*	*	***	*
• frequently reproduces naturally from seedling origin	**	***	***	***
• very rapid early growth rate if of vegetative origin	***	***	***	***
• relatively rapid early growth rate if of seedling origin	?	?	?	***
• when of clonal origin, very effective natural thinning	***	*	***	*
• natural thinning in seedling origin stands is less effective than in stands of stump or root sucker origin	?	**	?	*
• ability to fix nitrogen	*	*	**	***
• nitrogen fixation leads to soil acidification	*	*	*	***
• significant role in riparian ecosystems	**	***	***	***
• management for high quality solid wood products is a high priority	*	***	**	***
• management for fibreboard, strandboard, pulp, and paper products is main priority	***	**	***	**

Hardwoods differ from conifers in their leaves, bark, and wood, circumstances that result in the following distinctions between hardwoods and conifers:

- Most temperate hardwoods are deciduous and invest less energy than conifers into production of secondary compounds to deflect herbivory (Longhurst et al. 1968).
- Hardwood leaves host numerous herbivorous insects that benefit canopy-feeding birds and their leaf litter encourages a rich arthropod fauna that benefits many ground-dwelling insectivores (Bunnell and Dupuis 1993; Bunnell et al. 1999).
- The bark of many hardwood species is relatively rich in nutrients and has a higher pH than most coniferous bark
- Hardwoods are less resistant to decay than are conifers and thus provide cavity sites at relatively young ages compared to conifers; hardwoods also produce downed wood that recycles more quickly than coniferous downed wood.
- Hardwood cover may be advantageous over coniferous canopies because in winter hardood trees have less crown area (no leaves) when snow loads and windstorms are most intense as causes of blowdown (Bunnell et al. 1999).
- In a given climatic region, hardwood species usually contain more nutrients per unit biomass than conifers (Marion 1979), although Johnson (1983) emphasized that this subject must be addressed at the individual species level rather than as a generalization of differences between conifers and hardwood species.
- In general, understory areas in hardwood forests receive higher levels of solar radiation than in coniferous forest. This leads to higher forest floor temperatures in hardwood stands in early spring compared to conifer stands, which translates to higher rates of root growth, higher respiration rates in roots and microorganisms, more rapid litter decomposition, and more abundant shrub and herb biomass beneath hardwood stands than in coniferous stands (Monteith 1975).

7.2. Gap Dynamics and the Value of Hardwoods in Mixed Stands

Long ago forest managers recognized that mixed stands are more resistant to insects and diseases because there is less continuity of a single host species. There is also abundant recent documentation that mixed species stands involving hardwoods have greater biodiversity values than pure conifer stands. In addition to choices of species to maximize these mixed-stand benefits, there are challenges for managers who must decide if even-aged development of mixed hardwood-conifer stands is feasible (Oliver 1980).

In south Interior British Columbia, there has been important Ministry of Forests research recently on the values of hardwoods in mixed species stands (Simard and Nicholson 1990; Simard and Vyse 1994; Vyse and DeLong 1994; Simard 1996a, 1996b; Simard et al. 1997). Key points from this research are that management costs and root disease incidence are higher in pure conifer stands than in mixtures of conifers and birch. In addition, establishing mixed stands increases site productivity because birch foliage is richer in nutrients than conifer foliage and is recycled annually to the forest floor. Partly because of these ecological relationships, silviculturists now recognize three broad types of forests in southern British Columbia: old forests, some of which are being altered by partial cutting; maturing forests that have developed from fires of the early settlement period; and young natural or planted forests that have developed either from clearcutting or large fires in the past 40 years. Vyse and DeLong (1994) predict that the silvicultural focus in the foreseeable future will be on mixed species stands particularly for the young forests of the region.

Surprisingly, silviculture and forest ecology textbooks (Oliver and Larson 1990; Kimmins 1993) do not stress the importance of forest gap dynamics in forest stand development, probably because foresters have traditionally managed forests aimed at stand homogeneity for optimizing tree growth (Coates and Burton 1997). For shade intolerant species such as aspen, birch, and cottonwood the emphasis instead is that their abundance in mixed species stands is closely tied to the last major disturbance that initiated their establishment. However, in situations where these hardwoods are free of disturbance long enough to reach the stage of stem decay and stand breakup (typically 120 years or less) the gradual windthrow or snowload loss of decayed, weakened trees can result in stand openings where these hardwoods previously occupied crown space. Gap dynamics of aspen, birch, and cottonwood in the CBFWCP area is a poorly researched subject except for the Armillaria and other root rot relationships referred to in Section 6.2.2.

For inland ecosystems, some of the most detailed and recent research on forests stand gap dynamics has been by Cumming et al. (2000) for boreal aspen stands in northeastern Alberta and by Coates and Burton (1997), Kobe and Coates (1997), and Wright et al. (1998) for northwestern British Columbia. The latter researchers included data on aspen, birch, and cottonwood in the portion of the ICH Zone that occurs in the Nass Basin region. The degree to which these documented gap dynamic relationships apply the species mixes that occur in the Nelson Forest Region may require further research. However, several generalizations are probably applicable to hardwoods in the CBFWCP area as highlighted below:

- In northeastern Alberta aspen stands 44-67 years old, gaps began to form at about 40 years and gaps occupied 3.6 to 16.6% of stand area, increasing linearly with stand age (Cumming et al. 2000).
- Densities of aspen, birch, and balsam poplar saplings were 2-3 times greater in gaps than in paired control areas under a closed canopy. Sample plots in older aspen stands in the vicinity had spatially heterogeneous, uneven-aged structures, consistent with gap dynamics. Examination of forest inventory data sets indicated that this phenomenon is widespread (Cumming et al. 2000).
- The Cumming et al. (2000) evidence that aspen can regenerate in gaps is probably not applicable to the ICH Zone because Coates and Burton (1997) found that in gaps that were 34-41 years old aspen and cottonwood, two of the most shade intolerant species in the ICHmc Subzone of northwestern British Columbia, were not found in forest gaps. Birch (also very shade intolerant) did

rarely occur in some of the larger gap sizes (over 2400 m^2) in the ICHmc Subzone.

The Boundary Forest District analysis by Steeger and Hawe (1998) of old-seral stands in the IDFdm1 Variant noted the lack of information about canopy gaps in such forests. Aspen, birch, and cottonwood are constituent species of site series 05, 06, and 07 in the IDFdm1 Variant (Braumandl and Curran 1992) but Steeger and Hawe (1998) did not describe the roles of these hardwoods in gap dynamics. They did note that forest gaps are less frequent in the wet end of the moisture gradient (site series 05, 06, and 07 where the hardwoods most commonly occur) than in mesic or dry sites.

In the CBFWCP area there is a need for more research on the place of hardwoods in gap dynamics. In areas that experience large-scale disturbances, such as the stand-maintaining fires that define Natural Disturbance Type 4 ecosystems in parts of southeastern British Columbia, it is easy to overlook the role of small-scale low intensity disturbances. There is substantial literature on hypotheses about the ecological differences between large, infrequent disturbances and small, frequent disturbances (Romme et al. 1998). Research on this topic in British Columbia has shown that all forests undergo small scale, low intensity disturbances (gap dynamics) if they escape large-scale disturbance (Coates and Burton 1997) but what this means for hardwoods in the CBFWCP area is not well documented.

8. SOME SPECIAL MIXED STAND CIRCUMSTANCES IN PROJECT AREA

This review precluded fieldwork to observe and document special ecological circumstances of hardwood-conifer mixtures in the CBFWCP area. However, three examples are singled out: cottonwood-aspen co-occurrence in some alluvial ecosystems; circumstances where aspen occurs in the ESSF Zone; and abundance of hardwoods around Trail and in other industrially disturbed sites in southeastern British Columbia. All three examples are topics deserving more detailed documentation.

8.1. Cottonwood-Aspen Co-occurrence in Some Alluvial Ecosystems

Although cottonwood is the dominant hardwood in alluvial sites and riparian zones, it is important to recognize that these sites are not exclusive of aspen or birch. Aspen coexists with cottonwood on alluvial sites in the vicinity of Wasa and also in the Golden area. For example, where the Blaeberry River joins the Columbia River 16 km north of Golden, Fyles and Bell (1986) described vegetation that colonizes river gravel bars. As with other documentations of successional sequences that lead to riparian black cottonwood stands, these researchers demonstrated that distribution of plant communities on the gravel bars was controlled by variation in soil texture and water table depth. For the Populus Stable Bar Community Type, Fyles and Bell (1986) mention the presence of *Populus tremuloides*, although the accompanying text and species cover tables list only *Populus trichocarpa*. There are also examples of aspen coexisting with cottonwood on alluvial benches in the Trail-Castlegar area (K. Enns, pers. comm., Dec. 2000).

Similar co-occurrences of aspen and cottonwood are recorded for northwestern Montana. The detailed report by Hansen et al. (1995) on classification and management of Montana's riparian and wetland sites recorded three habitat types that contain aspen on alluvial terraces in the mountainous part of northwestern Montana (the aspen – red-osier dogwood, aspen – bluejoint reedgrass, and aspen – Kentucky bluegrass habitat types). The aspen- red-osier dogwood community is the most common of these three habitat types and in this type each of aspen, birch, and cottonwood coexists on alluvial sites. Where aspen occurs on alluvial sites in northwestern Montana, adjacent wetter sites are usually dominated by cottonwood and adjacent drier sites are usually by Engelmann spruce. The aspen - Kentucky bluegrass habitat type on alluvial sites was considered by Hansen et al. (1995) to be a disclimax community resulting from heavy grazing and browsing.

Cordes et al. (1997) also described the co-occurrence of aspen, balsam poplar, cottonwood (*Populus deltoides*), and white spruce on alluvial sites on the Red Deer River in Alberta.

8.2. Aspen in the ESSF Zone

Aspen's presence in the ESSF Zone of the Nelson Forest Region is most noticeable on south-facing slopes. In the Robson Valley Forest District, prominent examples of aspen on south-facing slopes in the ESSFmm1 Variant occur in the upper Holmes River valley near the British Columbia-Alberta border, east of McBride, and in the upper Fraser River valley at its headwater area near Yellowhead Lake, also near the British Columbia-Alberta border.

The presence of aspen in these subalpine altitudes is not well documented ecologically. There may be some applicable information from the lower foothills of Alberta where the tenacity and longevity of the aspen root systems were revealed (Horton 1956). He found aspen suckers in almost every coniferous stand regardless of age, density, or amount of conifers present. Even under very dense canopies of conifers there can be weak, inconspicuous aspen suckers most of which probably live only a few years. However, the important point is that a functional aspen root system can persist in what is considered, ecologically and silviculturally, to be a coniferous stand.

It is now known that aspen roots may persist for a long time in the absence of aspen stems in the canopy, nurtured only by transient root suckers beneath the coniferous canopy (Schier et al. 1985). As unusual as this may seem, there are old accounts to substantiate this point. For example, the review of suckering in *Populus tremula* by Bärring (1988) referred to an old German text (Hartig 1851) in which it was noted that even if aspen trees have long since disappeared the roots could survive in closed stands by scarcely noticeable suckers that emerge annually in the shade. This continuous process is enough to maintain an aspen root system for a very long time so that aspen, even in the ESSF Zone, can be a potential component of future stands even if it is not well represented now in aboveground aspen stems.

Reviews of the effects of climate change in subalpine forests of western North America (Luckman and Kavanagh 1998; Peterson 1998) make little or no reference to past, current, or projected distribution of hardwood tree species in subalpine zones. However, an important observation from these research reviews is that most of the tree species present today at high altitudes in western North America are thought to have occupied these sites for at least 10,000 years (Peterson 1998).

8.3. Abundance of Hardwoods in Vicinity of Trail, B.C.

An important point is that smelter effects are not the only influences of past industrial activities on today's distribution of hardwoods in southeastern British Columbia. Many areas that now support hardwoods are not a result of air pollution effects from a site-specific industrial-scale smelter, but rather the cumulative result of many fires that escaped from sites of previous open-air smelting and from sites that were logged to fuel large smelter energy needs (K. Enns, pers. comm., Dec. 2000).

In the vicinity of Trail, forest vegetation experienced two major impacts this century. First, after large numbers of fires between 1910 and 1930 vegetation recovery included an increased representation of hardwoods compared to the pre-fire period. Second, the main smelter output to the atmosphere was in the period between World War I and II, peaking in the period 1940-1945, and this had a further influence on forest vegetation that was recovering from fire disturbance. The main response was abundant establishment of shade-intolerant hardwoods, especially birch. In that area, birch that was established between 1940 and 1960 remains the dominant hardwood. This birch is now showing the first signs of breakup, especially on north-facing slopes where conifers are coming in. Much of this older birch now has an understory of Christmas-tree size lodgepole pine, western white pine, and Douglas-fir. Birch's main occurrence in the vicinity of Trail is from valley bottoms up to about 900 m. Birch occurs mainly on medium textured soils and aspen is more abundant on fine-textured glacial till and on coarse colluvium. Where aspen coexists with cottonwood on alluvial benches there is evidence that cottonwood is more resistant than aspen to industrially released SO_2. On many of the alluvial benches in the Trail area, lodgepole pine is now also becoming established among the cottonwoods or aspen (K. Enns, pers. comm., Dec. 2000).

Species most at risk from ozone exposure, based on observations in national parks and monuments of the Pacific Northwest which includes the United States portion of the Columbia Basin (Eilers et al. 1994), listed balsam poplar and aspen as species highly sensitive to ozone. Trees ranked as "sensitive" would be negatively impacted by a 7-hour growing season mean of 60-90 ppb for conifers and 70-120 ppb for hardwoods. The current mean seasonal ozone concentrations in that basin were significantly below that level. However, in summarizing ozone impact on vegetation, Schoettle et al. (1999) stated that ozone has the greatest potential of any air pollutant to directly influence growth and vigor of vegetation in the basin because it is highly phototoxic and is found globally in elevated concentrations. Ozone and its precursors can be transported hundreds of miles, and ambient air quality for ozone is less well characterized for this area of the United States compared to other areas. Ozone-induced stress may have secondary effects beyond reduced growth, such as increased susceptibility to root rots and insects (Schoettle et al. 1999).

9. LIMITED OCCURRENCE OF HARDWOODS IN OLD FOREST STANDS

When CBFWCP considers the role of hardwoods in relation to the province's Old Growth Strategy, it is instructive to note how other analysts have assessed the role of early seral tree species. For example, the old growth conservation strategy proposed by Robson Valley Forest District (1992) indicated that hardwood species and lodgepole pine, as early seral species, were not considered as candidates for representative old growth stands. However, birch was mentioned as a low priority species, along with white pine and whitebark pine, for consideration in overall special management area selection for old growth stands in the Robson Valley Forest District. It is relevant that the 1992 draft Robson Valley old growth conservation strategy emphasizes the importance of partial cutting systems that create openings where both conifers and hardwoods may regenerate.

In their assessment of stands over 140 years old in the Nelson Forest Region, Quesnel and Leahy (1993) and Quesnel (1996) recorded only minor occurrences of aspen, birch, or cottonwood in these older stands. Similarly, the review of old forest ecosystems in western national parks in Canada (Peterson et al. 1995), which included Yoho and Kootenay National Parks, identified only conifers and no hardwood species in various reports dealing with old forests. For example, aboveground expression of aspen clones rarely exists as very old aspen stems, even though the clonal root systems of aspen can be extremely old.

Aspen and birch are not well represented in age classes above 140 years (see Table 4.1 based on Fraser and Davis 1996). Therefore, these species do not figure prominently in old-growth ecosystems. Cottonwood reaches greater ages than aspen and birch, with about 9% of the area now occupied by cottonwood in the Nelson Forest Region represented in the 141-250 year age class and about 2% over 250 years old (Table 4.1). The important point for CBFWCP is that, in relation to old growth strategies, gap dynamics will generally ensure that there are some hardwoods present in most old conifer stands. However, such hardwoods are typically a minor stand component and not part of the old growth upper forest canopy. In general, the concept of old growth hardwood stands does not apply to the CBFWCP area.

10. POSSIBLE LONG-TERM TRENDS IN HARDWOOD DISTRIBUTION AND ABUNDANCE IN PROJECT AREA

An extraordinarily large number of publications about aspen begin with the statement that it is the most widespread tree species in North America, usually citing Fowells (1965) or Perala (1990a). As the most widespread species on a continent that offers a broad array of biogeoclimatic conditions, disturbance types, forest management approaches, and land-use alternatives it seems unlikely that aspen is going to disappear from any region that it now occupies. The earliest historical records indicate that aspen and cottonwood have been an important part of the landscape of western North America since the first exploration of the west (Bonnicksen 2000). His archived sources indicate that in the mid 1800s aspen groves occupied about 4% of the landscape in the Yellowstone area. In that era others estimated that aspen and cottonwood occupied about 2% of the overall forested landscape in the northern Rocky Mountains of the United States. Although their abundances may have changed over time, these hardwoods are an enduring feature of the landscape.

For the CBFWCP the important question is not whether the presence of these hardwoods is threatened but how may their abundances and distribution change with future land management policies and land use practices. Within a region such as the CBFWCP area the future may bring dramatic and unpredictable changes in disturbance regimes or land-use practices. There are now well-developed techniques for monitoring changing disturbance regimes at the landscape level (Sachs et al. 1998). Predicted climate changes may also bring unforeseen extreme weather events. However, there is no scientific basis at present to suggest that these possible major changes will greatly alter the overall abundance of early succession hardwoods that have persisted since the last glaciation. It is expected that aspen, birch, and cottonwood will be around for a long time,

Long-term trends in hardwood distribution and abundance will be influenced by changing disturbance regimes and land-use changes, as well as possible climate changes or extreme events which are discussed in subsections below. However, predictions of the long-term future of hardwoods in the CBFWCP area are fundamentally influenced by the adaptability of the species themselves. For example, vegetatively reproducing species such as aspen, birch, and cottonwood can have a regenerative system that is long lived. For aspen, the extreme recorded case is at the south end of the Wasatch Mountains in Utah where a clone has been nominated as the most massive living organism known. Made up of about 47,000 stems, this clone covers about 43 ha. It is estimated to weigh 5.9 million kg, nearly three times heavier than the largest giant sequoia (Grant 1993). Along with large clone size there is great clone age, and researchers have speculated that south of the limits of continental glaciation some aspen clones may reach an age of many thousands of years. Grant suggested that with vegetative reproduction there is no botanical reason why aspen clones could not be essentially immortal.

Opinion is divided about the longevity of aspen's clonal root system that is a reproductive reservoir able to produce root suckers. Examples of recent research themes include:

- Some researchers suggest aspen trees are being crowded out and stress that this is important because all trees in a stand share identical genetic makeup. When a clone disappears, its genes are lost and that type of aspen will never grow again (Gale 2000; Bartos and Campbell 1998).
- Most of the observed losses of the aspen cover type in the western United States are a result of succession to conifers especially at higher altitudes where

subalpine fir is becoming more common as a result of fire suppression policy. Gale (2000) refers to the prediction by Bartos and Campbell (1998) and others that aspen in the western United States will probably never again reach the full extent of its historically known presence. The degree to which this prediction applies to the CBFWCP area requires further study.

- The Utah example described by Grant (1993) does not mean that all aspen clones are long-lived. Kay and Wagner (1996) have examined repeat photosets of aspen communities in the northern part of the Yellowstone area dating back to 1871 and in that area one-third of the aspen clones have completely died out since that date. This is not necessarily an undesirable circumstance because Martin (2000a) has indicated that unhealthy aspen trees and deteriorating clones have important wildlife values.

To speculate on long-term trends of hardwoods in the CBFWCP area in relation to changes in disturbance regimes, land uses, and climate it would be possible to become immersed in the theory and assumptions of landscape ecology. Malanson (1993) has done that for riparian landscapes and the details of his review are not repeated here except to note the key principles of landscape ecology (Forman and Godron 1986) that pertain to riparian ecosystems. Two general principles stand out for application to riparian landscapes in the CBFWCP area:

- landscape heterogeneity decreases the area that represents interiors of forest ecosystems, increases the amount of edge conditions, and enhances species richness;
- nutrient flows in the landscape increase with the amount of disturbance.

Beyond riparian areas, landscape ecology concepts such as fragmentation, patch size, forest interior habitat, and edge effect have been considered in projects such as the ATLAS/SIMFOR Modelling Initiative in the Deer Creek Watershed and Pend d'Oreille Valley of the Nelson Forest Region (Steeger 1997). This modelling is design to predict consequences of certain harvesting activities on landscape patterns and habitats. For the present review we did not obtain specific information on what this model predicts for distribution and abundance of hardwoods in the CBFWCP area.

A key contribution of the report by Steeger (1997) is review of various definitions for the term 'forest interior'. However, regardless of the definition used for forest interior, there is little or no information on the role of hardwoods in southeastern British Columbia for defining ecological conditions in edge, interior, or patch locations of forest ecosystems. Yet it is known that hardwoods do vary in their abundance in patch, interior, or edge sites within forest stands. The undefined role of hardwoods in their various spatial distributions within stands is a topic for CBFWCP to consider for future research.

10.1. Possible Responses to Changing Disturbance Regimes and Land-Use Changes

The hardwood component of future forest stands will be influenced by a variety of land-use changes that result from provincial regulations or guidelines. For example, the riparian assessment and prescription procedures compiled by Koning (1999) for the Watershed Restoration Program recognize various management goals for hardwood-dominated riparian sites at stand ages 25, 70, and 150 years. Those alternative procedures include: felling hardwood trees to create openings for conifer plantings; aggressive stand tending of hardwood competition to ensure conifer survival; or management of hardwood stands for their own values. These alternatives are assumed to be possible management choices in the CBFWCP area where cottonwood is the dominant hardwood present in any given Landscape Unit. However, the various reviews of riparian management in relation to biodiversity maintenance in British Columbia, such as Stevens et al. (1995), are typically not specific to cottonwood or other hardwoods in the CBFWCP area.

Some reviewers have suggested that in southern parts of British Columbia aspen is declining in abundance as an inadvertent consequence of fire suppression, browsing, and possibly cutting practices (Bunnell et al. 1999). However, the main determinant of future hardwood stands will be logging and subsequent silvicultural practices aimed at optimizing production of conifers. Because hardwoods within conifer stands have not been the concern of long-term studies, there is little information in the literature on likely outcomes for hardwoods of present harvest regimes. Present silvicultural practices, with shortened rotations, try to reduce shrub and hardwood seral periods and overwhelm any potential hardwood clumps or individual hardwoods within stands through early planting of conifers.

The policy of suppressing all forest fires regardless of cause or location has generated strong words from fire ecology analysts. In reference to the Blue Mountains of northeastern Oregon, Pyne et al. (1996) wrote "The Blue Mountains have become a cameo of what has gone dreadfully wrong with the stewardship of American ecosystems. … they advertise a disaster, or worse a tragedy of good intentions and bad practices gone horribly awry. They have become a paradigm of forest health issues, of the complex and often contradictory demands on contemporary fire management, and of perhaps the greatest failure of prescribed burning programs, the fire that was never lit." In this context Pyne and co-authors point out that former aspen stands have degenerated, no longer rejuvenated by surface fires.

Deteriorating aspen clones have been documented for several decades in the western United States (see for example Schier 1975) and in Banff National Park (Kay et al. 1994). However, interest in how to restore declining aspen is more recent, as indicated by the work of Bartos and Shepperd (1999) and the soon to be published proceedings of a June 2000 conference *Sustaining Aspen in Western Landscapes*. Some of this current interest in aspen clone maintenance or restoration may apply to the CBFWCP area but it was beyond the scope of this review to assess the degree to which aspen deterioration is a concern in southeastern British Columbia.

Where there is visible evidence or suspicion of aspen decline, root system dynamics may be controlling current aspen status in certain circumstances. Attempts to age small-diameter roots in aspen clones date back to the study by Day (1944) who recorded annual rings in root cross sections to determine rates of root elongation. More recently, Schier (1975) recorded ages of small aspen roots in the 1-2 cm diameter class, the root size generally involved in sucker production. The possible presence of very old root systems in places where today's aspen clones are thought to have been present for many years or centuries is not a research priority. Grant's (1993) description of the largest (and possibly oldest) aspen clone recorded to date did not suggest that this clone had roots of an age equal to the great longevity of the clone. Even if an aspen clone is potentially immortal its components parts, including its roots, are continuously being renewed. Aspen root systems are less prone to the disturbances (fire, cutting, browsing) that impact aboveground parts of the clone but research shows that root connections between stems in a clone eventually die (Schier 1975). The similar root mortality is recorded for the main sinker roots of aspen stands, where the decayed root channels are re-occupied by new roots of the clonal system (Day 1944).

Another factor that could influence future distribution and abundance of hardwoods is restoration itself. There is now active interest to develop approaches and techniques for restoration of various forest types in western North America (Everett 1994; Morrison et al. 1994; Hardy and Arno 1996; Bartos and Shepperd 1999; Hardy et al. 1999; Parminter and Daigle 1999). Burton's (1999) assessment of silvicultural practices and forest policy in British Columbia from the perspective of restoration ecology presents an encouraging outlook. His optimism is based on the recent rapid growth of interest in restoration approaches (Maser 1990; Hammond 1991; Pilarski 1994; Voller and Harrison 1998; Egan 1999). An improving understanding of disturbance ecology (Parminter 1998; Gayton 1999) is an important part of these initiatives. Burton (1999) reviewed various definitions of restoration ecology and restoration forestry. Whatever definition is used, a unifying goal is to emulate the natural composition, structure, and functioning of now-degraded ecosystems in a manner that will leave them self-sustaining and integrated with the landscape in which they occur (Higgs 1997). In addition to Burton's examples of restoration ecology in relation to silvicultural practices, McLennan and Johnson (1999) provide other examples of restoration of ecological functions in British Columbia riparian ecosystems, largely a result of projects under the Watershed Restoration Program. Comparable initiatives exist for riparian restoration for the U.S. portion of the Columbia Basin (Wissmar et al. 1994).

10.2. Possible Responses to Predicted Climate Warming and Extreme Events

Canadian Rockies vegetation changes that were thought to be associated with a 1.5 °C increase in mean annual temperature over the last 100 years, and with inferred changes in precipitation regimes, appear to be driven as much by absence of major forest fires as by climate change itself (Luckman and Kavanagh 2000). Johnson and Larsen (1991) reviewed climatically induced changes in fire frequency in the southern Canadian Rockies. Extension of those observations to southeastern British Columbia is a subject too complex to analyze here. The important point for CBFWCP is to recognize that changes in frequency, size, and intensity of fires may be one of the most prominent expressions of future climate change. The implications for hardwoods of these possible fire-effect changes were beyond the scope of this review.

As a result of work by the Pacific and Yukon Region of Environment Canada and the Intergovernmental Panel on Climate Change, a website exists as a service to researchers involved in climate change impact studies in southern British Columbia (www.pyr.ec.gc.ca/climate-change/Scenarios.htm). For the Columbia Basin, climate data for 1960-1990 from Nelson. Cranbrook, Invermere, and Golden are used as the base with which to compare global climate model predictions of:

- predicted percentage change in total precipitation, by month, for the periods 2010-2039, 2040-2069, and 2070-2099, compared to 1961-1990;
- predicted change in mean maximum temperature (degrees C), by month, for the periods 2010-2039, 2040-2069, and 2070-2099, compared to 1961-1990;
- predicted change in mean minimum temperature (degrees C), by month, for the periods 2010-2039, 2040-2069, and 2070-2099, compared to 1961-1990.

These climate-modelling projections need to be examined in detail by anyone interested in the subject. To give one example, for the period 2010-2039 (referred to as the 2020s) the modelling does not predict any notable change in mean monthly precipitation for the Columbia Basin compared to the 1961-1990 baseline data. However, for the 2020s all global climate models project increases in mean maximum temperatures in each month compared to 1961-1990 records. This is supported by similar conclusions from United States studies in the Pacific Northwest (Hamlet and Lettenmaier 1999a, 1999b; Mote 1999). The same is true of predicted mean monthly minimum temperatures, with January, February, and March predicted to have mean minimum monthly temperatures 2.5 to 3.0°C higher in the 2020s than in the period 1961-1990. Recently observed reductions in the frequency of very cold winter events (prolonged periods with temperatures below –30° C) could have large influences on forest structure because these cold events control pine beetle populations which, in turn, influence not only forest structure but also forest management when there are large areas of beetle-killed forest. The implications for hardwoods for assumed increases in insect infestations are not yet clear.

Unfortunately, there are no research results to directly predict what such a climatic warming would mean for distribution, abundance, vigor, and regeneration of aspen, birch, and cottonwood in the Columbia River Basin. Hamlet and Lettenmaier (1999a and 1999b) suggest higher winter stream flow volumes and reduced flood peaks in the future. Although power production facilities can adapt to this change if overall flows are expected to remain about the same, this scenario has implications for riparian hardwoods along free-flowing reaches of the Kootenay and Columbia Rivers. Under this scenario, flood events that lead to subsequent establishment of new cohorts of cottonwood would occur less often.

The impact of climate change on North America's forests is continually under review (Joyce and Birdsey 2000). To put this accumulating information in perspective, it is helpful to focus on tree species that are representative of mesic sites which themselves are representative of regional climatic conditions. In the biogeoclimatic ecosystem classification system, mesic site series are by definition considered to be more reflective of the regional climate of a given subzone or variant than is the case for very dry or very wet site series. In the CBFWCP area this means that aspen and birch will be the best indicators of possible climate change influences because they occur most frequently on mesic sites rather than very wet or very dry sites. In contrast, cottonwood occurs predominantly on azonal riparian sites series. The word azonal by definition means that some topographic, geomorphic, edaphic, or local soil moisture factor overrides the influence of regional climate. Therefore, cottonwood will be less responsive to future climatic warming than aspen or birch may be. However, cottonwood could be greatly influenced if changing precipitation regimes alter the fluvial geomorphology dynamics of floodplains where cottonwood occurs.

For the three hardwood species of interest here, aspen is the only species for which there have been attempts to predict its response to climate change (Zoltai et al. 1991). Six independent global circulation models reviewed by Zoltai and co-workers all indicated mean annual temperature increases (ranging from 1.9 to 5.2°C) if there is a doubling of atmospheric CO_2 sometime in the 21^{st} Century. Four of the six models, including the Canadian Climate Centre Model, indicate expected increased summer dryness for mid-continental North America. The degree to which these predictions of warmer mean annual temperatures and increased growing season dryness will also apply to the valley and mountain terrain of southeastern British Columbia is not clear.

Assuming future higher mean annual temperature and increased summer drought in the Columbia River basin, extrapolation of predictions by Zoltai and co-workers to that part of British Columbia suggests the following aspen responses. Where aspen now exists on relatively dry sites, future growth rates will likely be reduced, along with higher mortality and higher incidence of insect and disease infestations. In biogeoclimatic subzones where aspen now reaches its altitudinal limit, range extensions to higher altitudes are likely, similar to the northward range of extensions predicted by Zoltai et al. (1991) for boreal and subarctic ecological zones. Some researchers (Pollard 1985) have generalized that fast growing species such as hardwoods are expected to be the favoured beneficiaries of enriched CO_2 levels in the atmosphere. Lacking similar predictions for birch, one can only assume that aspen's expected climate change responses might also apply to birch.

Mountainous terrain, as in the Columbia River Basin, offers opportunities to predict future vegetation/climate relations based on present topographically induced local climate differences. For example, slopes with southern or southwestern aspects are locally warmer and drier than other slopes and aspects, even though they share the same regional climate. Today's vegetation on such warmer and drier slopes may be predictive of future vegetation in other areas if the regional climate becomes warmer and drier during the growing season. For example, occurrences of aspen on many south-facing slopes in the

ESSF Zone, may be indicative of future vegetation at subalpine altitudes under a warmer regional climate.

Massie et al. (1994) recommended further testing of the hypothesis that hardwood forests could decrease in strategic importance in British Columbia with a climatic trend towards increased drought conditions. This is based on documentation (Lassoie et al. 1985) of several physiological contrasts between Pacific Northwest conifer and hardwood forests, including the suggestion that conifers may have an advantage over hardwoods during drought. For example, conifer needles exchange heat with the atmosphere better than leaves of hardwoods, thereby maintaining needle temperatures nearer to ambient temperatures. This is important during periods of drought-induced stomatal closure. Hardwood tree species are also considered to be inferior to conifers in internal water storage reservoirs; such reservoirs are important to moderate the effects of drought.

Hebda (1994, 1999) predicts that in British Columbia the greatest shifts in vegetation distribution as a result of global warming will be in dry interior biogeoclimatic zones. Mote et al. (1999) suggested that the lower tree line from ponderosa pine forest to sagebrush in Oregon and Washington could rise to a higher elevation. That scenario could occur in areas south of Trail and possibly proceed north along an elevational gradient to occur within the Canadian portion of the Columbia River Basin.

Although there is little documentation to date of likely responses of specific hardwood species to assumed climate changes, those who have studied the subject suggest that drought rather than cold has been the principal selective agent in the evolution of the deciduous habit in tree species (Stebbins 1972).

APPENDIX II. WILDLIFE USE OF HARDWOODS

DATA AVAILABLE

Hardwoods have several very important ecological attributes that are critical to their use by wildlife. The overall importance of hardwoods stands and hardwoods as a component of coniferous forests to wildlife is discussed in several important papers, the most recent and most comprehensive of which is Bunnell et al. (1999). There are several other papers we consulted that dealt with wildlife and hardwood species provincially (Enns et al. 1993), and several papers looking at the biology of hardwoods. Most of these papers were generated by an interest in the development of a hardwood forest industry in northeastern B.C. A wide range of papers discussing the importance of riparian areas and the role of cottonwood were also reviewed. Bird community studies in aspen stands in Alberta, north eastern B.C. and the Smithers areas were also of value as were a range of species specific bird and mammal studies carried out in B.C. and elsewhere. Our queries found less information on amphibians, reptiles and invertebrates.

Red and blue listed species are discussed in the main report. A table showing use of different hardwood age classes by listed species is provided below.

THE USE OF HARDWOODS BY WILDLIFE SPECIES AND SPECIES GROUPS

MAMMALS

BEARS: Black bear use catkins and new leaves of aspen in spring in northern B.C. and occasionally in the Kootenays (pers. observation- B. Jamieson). Grizzly bears make use of riparian areas, generally in the spring (B. McLellan, pers. comm.).

UNGULATES: Hardwoods provide a source of browse for all ungulates as has been documented in numerous studies. Riparian and hardwood areas provide browse during deep snow periods, a factor that is probably critical to over-winter survival and reproductive performance in elk, deer and moose in the Trench in deep snow years (R. Demarchi, pers. comm.). These stands also provide summer thermal cover.

FISHER: Natal dens of fisher are found within large diameter (> 90 cm diameter) cottonwoods, aspens, true firs and ponderosa pine (Powell and Zielinski 1994, Weir 1995, Paragi et al. 1996). These cavities are created by pileated woodpecker nesting activity, broken limbs and decay. In B.C., the larger dens required are most often found in cottonwood and generally in riparian areas (Banci 1989, Fontana et al. 1999, Forest Practices Code 1997).

MARTEN: Ruggiero et al. (1994) found 27 natal dens in trees and 19 in snags of 116 dens found, suggesting that tree cavities are less important for marten than they are for fisher. Prey availability, which depends on coarse woody debris and subnivean space (under snow air spaces, also provided by large woody debris) is critical for marten (several papers in Ruggiero et al. 1994). Complex riparian forests provide the downed wood and shrub layer required to create such circumstances. Most more recent papers concentrate on forest harvest impacts on marten, with surprising little work on their use of cavities.

PORCUPINE: The porcupine feeds on a variety of herbs and shrubs during spring and summer months. During winter the porcupine's food habits shift to an almost exclusive diet of bark of hardwoods and softwoods (Costello 1966). The porcupine removes the outer bark of these trees and feeds on vascular tissues (cambium and phloem) and to a lesser extent on lateral tips of branches. One assumes that hardwoods would be more palatable for porcupines based on the higher food value of hardwood tissue, but there appears to be little evidence to support this supposition (Harder 1979).

BEAVER: Beaver play a pivotal role in riparian processes, both in smaller streams where their dams alter hydrologic and nutrient regimes in major ways (Naiman et al. 1988) and in larger streams where they live in bank burrows and alter vegetation through their feeding activities. Felling by beaver is a major form of mortality for hardwoods since hardwood species are important food sources for beaver.

HARES AND RABBITS: Hardwoods are an important food source for hares and rabbits and have been studied extensively in the boreal forest, especially in relation to the cyclical population changes that occur for hares. These species are uncommon in the Columbia Basin compared to boreal areas.

BATS: Riparian areas and hardwood species are both important to a range of bat species. Vonhof and Gwilliam (2000), found that two large bats, the big brown bat and silver-haired bat showed a marked preference of older age aspen as roosting sites. They used hollows, cavities and cracks in aspen in preference to other tree species. Riparian areas are critical for foraging due to high insect numbers in riparian areas and high numbers related to the presence of cavities. Brigham (1991) found bat colonies in large dead ponderosa pine trees, but noted that foraging occurred along a nearby river. Grindal et al. (1999) found bat activity was much higher in riparian areas than in non-riparian areas, probably due to higher insect levels. Higher incidence of useable cavities and sites for roosting and nesting may also contribute to this higher use. Crampton and Barclay (1995) found a high incidence of use of cavities in aspen in mixedwood stands in Alberta. Brigham et al. (1997) found that large dead trees were preferred as roosting sites in southeast B.C. Grindal and Brigham (1999) found that edge areas were important for bat foraging, suggesting that the complexity of habitat types and open areas found in riparian areas likely makes them important for bats. On Vancouver Island, Grindal and Trofymow (1998) found that roost trees were most often in old-growth stands, and commuting activity was greatest in riparian areas.

SQUIRRELS: Carey et al. (1997) suggested that northern flying squirrel populations are limited by the availability of den sites and food. Cavities are a major component of flying squirrel den sites in Alberta (McDonald 1995). It appears that the cavities, habitat complexity and greater food resources (mushrooms) of riparian areas make them more attractive for this species. A hardwood component in the forest would increase all three of these factors. Cavities are also important to red squirrels thus contributing to the importance of the hardwood component in conifer stands for this species.

SMALL MAMMALS (MICE AND VOLES): Small mammals use hardwood shoots as a source of forage. Gomez and Anthony (1998) and McComb et al. (1993) found that species richness was similar between upland and riparian habitats (different species) but that capture rates and thus, we assume, density, was greater in riparian areas. Gomez and Anthony (1998) found the highest capture rates in hardwood stands and progressively lower rates from shrub communities to older age coniferous forests. Hanley and Barnard (1999) found no differences in food availability between upland and riparian habitats for Sitka mice, but noted that spatial and temporal complexity within habitats is an important feature of habitat quality in floodplain forests.

BIRDS

BALD EAGLE: Both conifers and hardwood species on stream banks are used by bald eagles for roosting and nesting (Dellasala et al. 1998, Stalmaster and Kaiser 1997, Isaacs et al. 1996, Garrett et al. 1993, Anthony and Isaacs 1989, Fielder and Starkey 1986), in part depending on availability. Larger diameter trees are preferred. Campbell et al. (1990) found in B.C. that 67% of eagle nests (n=63) were in deciduous trees.

GOLDEN EAGLE: Golden eagles use riparian areas and large cottonwoods during migration along the Kootenay River (B. Jamieson, pers. observations). Overall habitat quality and carrion availability in riparian areas is probably the determining factor for this use.

OSPREY: Osprey nest in large cottonwoods in the Creston area (Steeger et al. 1992) and in the Columbia Wetlands (Forbes et al. 1985). Riparian habitat quality and fish availability are other primary determinants in their presence. They also use power poles and snags as nesting sites.

CAVITY NESTING HAWKS AND OWLS

Data on the use hardwoods for nesting by hawks and owls is provided in Table 1.

AMERICAN KESTREL: Kestrels are primarily cavity nesters (73%). About 30% of kestrel nests were found in hardwoods (Campbell et al. 1990).

WESTERN SCREECH OWL: The Western Screech Owl is the only red listed species (Kootenay Lake, Cranbrook, Invermere, Columbia Forest Districts) in the study area. This is a non-migratory owl that is common on the coast but rare to uncommon in the central interior and is listed as very rare in the Kootenays (Campbell et al.1990). It nests in deciduous and coniferous riparian habitats at lower elevations and in urban areas below 540 m. It is a cavity nester although most nests (87%) are found are in nest boxes (Campbell et al.1990). Enns et al. 1993 suggests that they need trees >30 cm dbh. This would suggest that older age hardwood stands are important for this species if it occurs in the study area.

NORTHERN SAW-WHET OWL: This species uses mixed forests and its nests are often found in smaller diameter aspen (43-56cm. 30-40 years old). 64% of nests were in cavities in hardwoods; 7 of these were in woodpecker holes (Campbell et al.1990).

PYGMY OWL: This very small owl nest in cavities in conifers at higher elevation but winters at lower elevations where it may use hardwood cavities (Campbell et al.1990).

BOREAL OWL: This owl is generally found at higher elevations. It uses aspen in the north but generally uses conifers in the south of province.

BARN OWL: This is a very rare owl in this area. 93% of its nest sites were in human structures with 10 in cavities (Campbell et al.1990).

N. HAWK OWL: This is a very rare owl in this area. Campbell et al.(1990) notes that 3 nests found in BC were in cavities.

BARRED OWL: This owl is a recent arrival in B.C. Four nests of eight have been found in cavities. It is very rare in the study area.

Table 1. Use of hardwood species by hawk and owl species for nesting.
(Based on data from Campbell et al. 1990).

Species	Sample Size	Use of hardwoods
Cavity Nesters		
American Kestrel	261	27%
W. Screech Owl	62	
N. Saw-whet Owl	31	64%
Pygmy Owl	5	0%
N. Hawk Owl	3	
Barred Owl	8	
Using stick nests		
Bald Eagle	63	67%
Long-eared Owl	61	93%
Great Grey Owl	6	33%
Great Horned Owl	75	43%
Red-tailed Hawk	??	44%
Swainson’s Hawk	14	36%
N. Goshawk	21	46%
Cooper’s Hawk	62	37%
Merlin	14	14%

NESTING BUILDING HAWKS AND OWLS

Several hawk species use hardwoods for nesting. The data in Table 1 would seem to suggest they show some preference for hardwoods as nesting sites. The use of hardwoods by northern goshawks is noteworthy. The broad-winged hawk is keyed to aspen stands in the north east, but is rare in the study area (1 observation in Campbell et al. 1990).

GREAT BLUE HERON: Great blue herons nest in rookeries located close to water and fish foraging areas, almost always in large cottonwood stands (Forbes et al. 1985). They are dependent on riparian habitat quality, (fish, frogs, etc.) and habitat elements for roosting and nesting.

BELTED KINGFISHER: This species uses streamside hardwoods and conifers for perching. It nests in clay banks and is dependent on fish as a food source.

WATERFOWL: Common merganser, hooded merganser, bufflehead, Barrow's goldeneye and Common goldeneye make extensive use of cavities for nesting. From 88 to 100% of recorded hooded merganser, bufflehead, Barrow's goldeneye and common goldeneye nests were in cavities or nest boxes (Campbell et al. 1990). Common merganser is more varied in its choice of nest sites but it uses cavities and nest boxes 64% of the time.

RUFFED GROUSE: Aspen stands provide basic food and habitat across the range of the species (Johnsgard 1983). In a detailed study in Kluane National Park, Yukon, Martin et al. (2000) found ruffed grouse used only aspen stands. There is extensive literature on ruffed grouse in the boreal zone. Ruffed grouse seem to be tied to aspen areas, or at least stands with a hardwood component, but no habitat work has been done on this species in the Basin. (W. Warkentin, pers. comm.).

COLUMBIA SHARP-TAILED GROUSE: Studies in northern Montana (Yde and Olsen 1984, Wood 1991) and in British Columbia (Van Rossum 1992, Ritcey 1995) indicate that hardwood trees and shrubs are essential habitat components for sharp-tailed grouse and are no less important than grass or herbaceous cover in supporting a population. The buds and catkins of hardwood trees and shrubs are important sources of mid-winter food. Riparian areas along the Kootenay River and aspen stands in the Trench were probably critical to the sharp-tailed populations in many areas of the Trench (Ohanjanian 1990) before they were extirpated.

PILEATED WOODPECKER: Ohanjanian (1991). use low elevation forests and require large diameter, older age trees and snags for nesting. They are a critical component within forests since their nesting cavities are used by a wide range of other species, especially in riparian areas. This species requires large ponderosa pine, black cottonwood and western larch trees and snags as nesting habitat. Data from Campbell et al. (1990) suggest that 70% of pileated nesting cavities are in hardwoods. Aspen and birch rarely achieve sufficient size to be used by pileated woodpeckers. Ohanjanian (1991) surveyed forest sites with trees of sufficient diameter for pileated woodpecker nesting in the East Kootenay. She suggests that trees over 24-inch dbh should not be harvested, that logging plans should attempt to maintain large cottonwood trees in riparian areas and that large western larch snags should be retained where possible. Larch veterans are presently being left in lodgepole pine clearcuts in many areas. These sites are of low value to this bird species for the immediate future since they are slow flyers and are at risk to avian predators when nesting in open forest stands or clearcuts (Bull and Meslow 1977)). They may be of value in the later portions of the rotation when the second growth forest is > 10 m in height. Hartwig (1999) lists several studies that indicate that carpenter ants are the most important component of pileated woodpecker diet. We found no data to suggest that these prey species are more common in riparian habitats or hardwood stands. Several authors have noted the use of cottonwood by pileated woodpeckers for nesting and feeding cavities. Hartwig (1999) lists the following as using pileated woodpecker cavities:

- wood duck
- bufflehead
- common merganser
- hooded merganser
- common goldeneye
- Barrow's goldeneye
- American kestrel
- northern saw-whet owl
- northern pigmy owl
- boreal owl
- western screech owl
- red squirrel and northern flying squirrel
- pine marten and fisher
- woodrats.

Most of these birds and mammals use predominately hardwood tree species and many can only use pileated woodpecker cavities since they require a relatively large cavity. Weak excavators such as northern flicker and downy woodpecker use pileated woodpecker cavities where they are available. Brown creeper and hairy woodpecker use pileated woodpecker cavities for roosting. Feeding cavities provide feeding opportunities for red-breasted nuthatch, brown creeper, hairy and downy woodpeckers. Although they generally usually smaller cavities, swallows, bluebirds, chickadees, house wren, rough-winged swallow, starling and swifts also use pileated woodpecker cavities.

LEWIS'S WOODPECKER: Lewis's Woodpeckers use riparian cottonwood adjacent to grasslands in the Okanagan and in the Castlegar area (Cannings et al. 1987, Cooper 1996). The Libby Reservoir probably flooded the majority of the habitat where these circumstances may have occurred in the East Kootenay. Of 215 nests noted in Campbell et al. (1990), 47% were in cavities in hardwoods, most of which were cottonwoods.

OTHER WOODPECKERS: Other smaller woodpeckers are also important users of hardwood trees (Steeger et al. 1996). Red-naped sapsucker, downy woodpecker, hairy woodpecker, and northern flicker all make significant use of hardwoods for nesting (Table 2) and feeding. These species create and use smaller cavities that are also important for bluebirds, tree swallows and violet green swallows. Sapsuckers release sap used by songbirds, squirrels, hummingbirds, wasps, butterflies and other woodpeckers. Machmer et al. (1995) looked at the use of paper birch by cavity nesters in the Nelson area. They showed a strong preference for birch and aspen over conifers for nesting. Other woodpeckers that generally use coniferous forests (Williamson's sapsucker and Northern three-toed) show some use of hardwoods within conifer forests.

The yellow-bellied sapsucker is keyed to aspen in the north and the red-breasted sapsucker, found in the western half of the province is keyed to hardwoods. The white-headed woodpecker found in the Okanogan uses conifers only.

Table 2. Use of hardwood by woodpeckers.
(Based on data from Campbell et al. 1990).

Species	Sample Size	Use of hardwoods
Pileated woodpecker	NA	70%
Lewis's woodpecker	215	47%
Red-napped woodpecker	273	91% (73% in live trees)
Downy woodpecker	98	81%
Hairy woodpecker	155	69%
Northern Flicker	731	48% (hardwoods or boxes)
Northern Three-toed wp	63	18%
Williamson's sap-sucker	28	18%
Black-backed wp	18	0%

SONGBIRDS

Several studies have confirmed that cottonwood and aspen stands support much higher levels of bird diversity and bird density than do conifer forests as described in the main report. Several bird species show a preference for hardwoods for nesting (Table 3).

Table 3. Use of hardwood by selected songbird species.
(Based on data from Campbell et al. 1990).

Species	Sample Size	Use of hardwoods
Magpie	283	41%
American Crow	245	59%
Morning Dove	169	48%
Band-tailed Pigeon	31	26%
Calliope hummingbird	47	47%
Black-chinned hummingbird	11	100% (including fruit trees)
Rufous hummingbird	235	16%
Red-breasted nuthatch	143	30%
Mountain chickadee	139	55%
Black-capped chickadee	NA	(high preference)
Red eyed Vireo	48	81%
Mountain bluebird	2738	96% (trees and boxes)
Bullock's Oriole	463	91%
Redstart	98	55%
White-throated sparrow	NA	(ground nesting in aspen)

The extensive aspen forests of the Peace River basin in north eastern B.C. support a wide range of songbirds that do not occur here. Many of these are keyed to aspen stands. A total of 17 songbirds occur there (13 warblers) that are uncommon or rare in the remainder of the province (Table 4). Of these, 8 have been observed in the Robson Valley (Leung and Simpson 1993) and 9 in the Golden area (Campbell et al. 1990, Leung and Simpson 1993). Most are uncommon or rare in these areas.

Of these, the Philadelphia Vireo, Cape May Warbler, Black-throated Green Warbler, Bay-breasted Warbler, Connecticut Warbler and Canada Warbler are listed by the CDC for the Fort St. John forest district. None are listed for forest districts in the study area.

Table 4. Boreal songbirds that occur in Peace River and in the study area. (Based on data from Campbell et al. 1990, Leung and Simpson 1993, 1994).

Species	Peace River	Robson Valley	Golden
Baltimore Oriole	X		
Ovenbird	X	X	X
Grey Catbird	X	X	X
Philadelphia vireo	X	X	
Chestnut sided warbler	X	X	
Black-throated Green Warbler	X		
Tennessee warbler	X		X
Connecticut warbler	X		X
Cape May warbler	X		X
Palm warbler	X	X	X
Mourning warbler	X		
Canada warbler	X		
Bay-breasted warbler	X		
Black and white warbler	X		X
Magnolia warbler	X	X	X
Blackpoll warbler	X	X	X
White-throated warbler	X	X	
Total	**17**	**8**	**9**

REPTILES AND AMPHIBIANS

Gomez and Anthony (1996) and McComb et al. (1993) found changes in species and an increase in abundance of reptiles and amphibians in riparian and riparian hardwood stands.

FISH SPECIES

Streamside cottonwoods (and conifers) are an important habitat element for all salmonids, included the blue-listed cutthroat trout and bull trout. Large cottonwoods provide shade on some streams and thus modify water temperature. They also provide a source of terrestrial invertebrates that are used by fish. Judith Li and others in the United States have also documented major contributions to nutrient levels and insect food sources to salmonids from riparian vegetation (J. Li, pers. comm.). When cottonwoods fall into rivers and streams they provide fish cover and provide substrate for invertebrates that in turn act as another food source for fish. When large bole cottonwoods are washed downstream they often form log jams which provide important pool habitat and alter river mechanics in subtle but important ways (Braatne et al. 2001).

RED AND BLUE LISTED SPECIES

Several listed species are discussed above. Table 5 provides a summary of their use of hardwoods.

Table 5. The use of hardwoods by red and blue listed species.

Species	Age Class 1+2 0-40 years	Age Class 3-4* 41-80 years	Age Class 5-8** 81-250 years
Fisher			[use large cavities as natal nests]
S. T. Grouse		[winter cover and feeding]	[winter cover and feeding]
W. Screech Owl			[feeding and cavity nesting]
Lewis's woodpecker			[cavity nesting near grasslands]
Great Blue Heron*			[canopy nesting close to water]
Bull Trout			[important habitat element]
Cutthroat Trout			[important habitat element]

* Only large diameter trees and snags are used due to the size of cavity nest site required.
** Use of cottonwoods by Lewis' woodpecker is rare in the study area.

APPENDIX III. AN INVENTORY OF HARDWOODS, USING FOREST COVER DATA, FOR THE COLUMBIA BASIN.

Introduction

Digital forest cover data for the CBFWCP area was queried to generate a series of spatial databases and maps for each forest district within the compensation area. Results of this query process include, for each district, all forested polygons, all polygons with a hardwood component, and a breakdown of the polygons with a hardwood component for percent coverage and age class of each of the three main species, aspen, birch, and cottonwood, within each landscape unit. These query results were then displayed on maps and tabulated in spreadsheets. Due to the large size of the maps and the many columns of the spreadsheets, the four maps for each landscape district at 1:250,000 scale are provided in Acrobat PDF format and the spreadsheets as Excel files on the CD-ROM version of this report only. The top ten landscape units, in terms of polygon area, for each species and all hardwoods are shown in figures 3-7 in the main body of the report. A portion of one of the 1:250,000 maps is shown in figure 2.

Digital Forest Cover Data in BC

Digital geographic information system (GIS) forest cover data is maintained by the Resource Inventory Branch of the BC Forest Service for most public forest lands in BC[1]. Coverage includes all Timber Supply Areas (TSAs), recently-established parks, and some Tree Farm Licenses (TFLs). These data are comprised of a spatial file (FC1) and an attribute file (FIP) for each of the 7000 1:20,000 map sheets in the province. Each forest district is charged with updating these map sheets with quality assurance provided by the Victoria head office. As the forest cover database is one of the older GIS projects of the BC government, it exists in a GIS environment (PAMAP or Intergraph GIS) that differs from most other datasets (which are in Arcinfo GIS format), restricting the ability to synthesize different datasets, such as landscape units, with forest cover data. Some forest districts have addressed this problem by converting all their data to Arcinfo. Due to the compilation of data at the forest district level, and because of the different initiatives and strategies for data conversion undertaken in different districts, we decided to undertake the hardwood analysis on a district by district basis.

Forest Districts in the Compensation Area

The CBFWCP Compensation Area includes most of Arrow, Kootenay Lake, Cranbrook, Invermere, Columbia, and Robson Valley forest districts. All of these districts except Robson Valley are within the Nelson Forest Region and the Kootenay/Boundary Region of the BC Ministry of Environment, Lands,and Parks. Invermere and Arrow Districts have converted their forest cover data to Arcinfo, and MoELP has converted the data from Kootenay Lake, Cranbrook, and Columbia districts into Arcinfo as well. The Columbia District is a recent amalgamation of the Golden and Revelstoke forest districts and the forest cover databases are currently maintained separately for the former Golden and Revelstoke district areas by MoELP. In their conversion process, MoELP loaded all FIP tables into Oracle database tables. CBFWCP used MOELP's conversion tools to convert and compile Robson Valley forest cover data obtained from the Omineca Forest Region into Arcinfo and Oracle.

FIP data structure and the hardwood analysis algorithms

The FIP forest cover attribute data are one-to-many databases. This means that for each polygon in the FC1 spatial database, more than one record can exist in the associated FIP tables. For instance, the FIP database stores one record for each layer in a multi-layered canopy forest polygon. In a multi-layered canopy, tree species create distinct layers at different heights above the ground. Up to five of these canopy layers can be described and recorded in FIP for a single polygon. The layers are given a layer code, 1 (highest), 2 (next highest), 3 (lowest), V (veteran) or S (silviculture). The layers 1 to 3 are ranked for

[1] See http://www.for.gov.bc.ca/resinv/products/digdata/brochure.htm#Background

importance – it is not always the case that the highest layer above the ground is the most import layer from a forestry perspective. The Arcinfo datasets for the Invermere and Arrow districts are one to one databases: each forest polygon is linked to the record for the rank 1 layer. During the conversion process the non-rank 1 layers have been lost. However, for most of the compensation area we were able to query the complete FIP database as the one-to-many relationships are preserved by loading FIP into Oracle. The presence of hardwood forest species in the non-rank 1 layer is shown on the maps of the other districts and recorded on associated tables.

The analysis of hardwood forests was undertaken for each forest district using either a query of Arcinfo's Info tables (Arrow, Invermere) or the Oracle tables (Cranbrook, Kootenay Lake, Revelstoke, Golden, Robson Valley). The first step in both algorithms was to select all forested polygons. The item TREE_SPECIES_PCT_1[2], the percent of the leading tree species, was used in this selection process: every record for a forested polygon must have a non-zero value for this item. Next the records with a hardwood species in any of the 6 leading species for any record in the rank 1 layer (Arrow, Invermere), or any layer (the other districts) were selected. The polygons with a hardwood component were then divided into percent cover classes to distinguish between pure (81-100% hardwood), significant hardwood (41-80%), mostly softwood (21-40%) (21-80%), and minor hardwood (1-20%) stands. This breakdown was done for each of the three main species (aspen, birch, cottonwood) and for all three combined. Only the rank 1 layers were considered in the percent cover analysis.

The total forest and hardwood forest polygons were then overlain with landscape unit polygons to enable reporting on a landscape unit basis. The attached spreadsheets provide summary statistics for each landscape unit, including total forest, total hardwood forest, and then breakdowns by species, percent cover class, and age class. Four maps were produced showing landscape unit boundaries and the percent cover classes for each hardwood species and all hardwood species for each forest district.

Missing Data

Several significant gaps in the data exist. The large national parks in the compensation area, Glacier, Kootenay, and Mt Revelstoke, were not inventoried by the forest service as they had already been removed from the land base available for timber harvesting. Private lands are not consistently covered by the forest inventory database; as a result there are significant information gaps in the low elevation valley bottoms where most settlement occurs and in the large landholdings in the Elk Valley. TFL 14 in Invermere was not included in our analysis as the licensee has not provided forest inventory data to MoELP.

[2] see http://www.for.gov.bc.ca/resinv/reports/rdd/rdd.htm for a full description of all FIP attributes

Deciduous Forest Summary by Landscape Unit

Arrow Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
N501	SHEEP	36051.82	28364.97	3557.98	13	225.70	1	1764.90	6	1976.09	7
N502	ROSSLAND	28646.02	20913.82	9730.45	47	692.52	3	4005.20	19	8531.14	41
N503	BEAR	39215.80	27189.10	9256.69	34	456.61	2	4787.22	18	7068.63	26
N504	PEND OREILLE	19824.91	14259.64	5415.57	38	136.12	1	3180.43	22	3261.19	23
N505	STAGLEAP	57279.65	39594.48	12731.60	32	1078.62	3	3044.60	8	11611.49	29
N506	ERIE	40697.58	26733.72	9576.60	36	386.13	1	2158.70	8	8426.78	32
N507	GLADE	21635.17	15781.32	4614.40	29	91.91	1	2049.12	13	3566.98	23
N508	BLUEBERRY	32824.91	27285.90	6357.37	23	884.32	3	3239.80	12	4435.48	16
N509	DOG	24401.25	22524.64	3836.58	17	129.83	1	2705.67	12	1713.65	8
N510	JOHNSTON	39325.46	35585.76	2678.45	8	147.84	0	1490.56	4	1349.09	4
N511	CAYUSE	29743.26	27340.47	2963.91	11	151.26	1	2300.37	8	986.46	4
N512	LADYBIRD	46802.67	36930.02	4218.15	11	230.95	1	2243.57	6	2467.27	7
N513	PEDRO	19487.92	15839.14	2098.56	13	181.46	1	809.75	5	1391.33	9
N514	PERRY	18014.38	14615.15	2983.71	20	425.58	3	1559.25	11	1504.73	10
N515	LEMON	40941.99	33591.70	1169.75	3	144.49	0	890.25	3	475.15	1
N516	HODER	55024.03	32120.90	4417.38	14	206.58	1	2936.71	9	2255.61	7
N517	KOCH	49935.54	38043.17	1142.24	3	174.56	0	569.63	1	561.24	1
N518	GLADSTONE	37166.49	30745.99	2524.57	8	219.21	1	2081.42	7	387.76	1
N519	EAGLE	48378.87	44468.33	6565.68	15	880.73	2	1608.70	4	4613.87	10
N520	BARNES-WHATSHAN	61100.40	51210.67	7543.41	15	1639.52	3	5027.92	10	2017.09	4
N521	WODEN	32076.72	23270.76	2563.20	11	359.43	2	1864.99	8	1044.61	4
N522	CARIBOU	40154.93	33875.57	1986.75	6	201.07	1	1401.62	4	658.23	2
N523	HILLS	41659.30	28073.60	4430.81	16	150.03	1	3153.28	11	2278.42	8
N524	IDAHO	38262.33	26937.11	4415.25	16	25.58	0	510.53	2	4093.84	15
N525	WILSON	58854.46	36274.76	4728.99	13	360.85	1	1457.91	4	3440.74	9
N526	VIPOND	38794.43	35665.42	6759.39	19	1109.46	3	5231.96	15	1151.29	3
N527	FOSTHALL	55946.04	44428.13	4261.53	10	1246.90	3	2437.32	5	919.31	2
N528	KUSKANAX	45799.75	31647.64	1015.47	3	274.16	1	703.91	2	125.84	0
N529	HALFWAY	76320.62	58083.63	5315.32	9	719.41	1	4075.90	7	961.02	2
N530	TROUT	73346.66	39739.81	930.09	2	583.65	1	249.54	1	96.98	0
N531	FISH	89746.95	33593.53	3376.90	10	2000.36	6	1173.16	3	387.73	1

Deciduous Forest Summary by Landscape Unit

Cranbrook Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
C01		30573.68	27467.41	1801.65	7	613.83	2	15.59	0	1336.46	5
C02		53163.48	48142.08	3710.58	8	503.10	1	223.38	0	3380.68	7
C03		12988.41	12124.49	244.55	2	111.26	1	0.00	0	133.28	1
C04		40898.63	32387.99	852.55	3	359.73	1	54.14	0	486.39	2
C05		38572.28	29896.01	2003.15	7	474.17	2	105.52	0	1571.73	5
C06		56286.25	30483.91*	895.27*	3*	381.29*	1*	0*	0*	513.98*	2*
C07		38161.49	21742.4*	1207.82*	6*	711.53*	3*	89.49*	0*	551.75*	3*
C08		34236.55	28158.79	630.01	2	247.09	1	11.31	0	371.61	1
C09		36076.61	34134.11	773.38	2	61.31	0	5.78	0	721.27	2
C10		35744.96	32726.04	455.87	1	186.66	1	47.37	0	278.07	1
C11		29349.65	26593.28	304.17	1	33.14	0	11.69	0	266.71	1
C12		19683.41	17506.76***	136.12***	1***	6.18***	0***	0***	0***	129.93***	1***
C13		20869.21	17410.80	1000.19	6	73.53	0	343.39	2	762.40	4
C14		30948.12	24284.94	1220.82	5	115.94	0	68.59	0	1041.89	4
C15		41495.23	24649.28**	2662.96**	11**	172.44**	1**	1148.42**	5**	1920.11**	8**
C16		53755.61	40172.11	2201.04	5	728.85	2	0.00	0	1553.43	4
C17		30658.19	20667.73**	385.62**	2**	97.38**	0**	0**	0**	288.42**	1**
C18		73129.94	49452.83	4473.18	9	1656.27	3	4.17	0	2950.49	6
C19		41133.54	10161.65**	1759.09**	17**	109.75**	1**	0**	0**	1696.78**	17**
C20		33032.30	14769.46**	707.64**	5**	145.45**	1**	0**	0**	564.98**	4**
C21		44200.86	17097.78**	407.02**	2**	145.88**	1**	0**	0**	261.14**	2**
C22		66326.18	28776.28****	1799.28****	6****	317.8****	1****	0****	0****	1616.69****	6****
C23		64447.68	38896.20	3944.91	10	1592.53	4	72.83	0	2998.48	8
C24		70631.00	25804.58**	9901.47**	38**	4563.76**	18**	1257.97**	5**	7976.75**	31**
C25		18806.33	12315.39	1153.89	9	142.95	1	505.78	4	622.45	5
C26		38735.97	26507.46	3481.86	13	76.17	0	963.00	4	2758.47	10
C27		61972.79	33144.89	889.71	3	30.83	0	18.11	0	840.93	3
C28		49133.40	30132.09**	2975.32**	10**	188.73**	1**	867.26**	3**	2242.62**	7**
C29		32830.09	23398.25	1465.51	6	606.75	3	516.90	2	487.19	2
C30		46224.75	32197.25***	3499.77***	11***	1071.69***	3***	34.49***	0***	3179.71***	10***
C31		20294.54	18106.49	1373.78	8	103.76	1	175.36	1	1253.42	7
C32		31781.48	21277.79	3483.37	16	840.29	4	217.47	1	3167.52	15
C33		31800.47	22227.89	2112.00	10	623.78	3	106.95	0	1917.21	9
C34		46829.10	31998.08	3777.05	12	338.45	1	891.33	3	3176.58	10
C35		20621.10	13568.47	58.10	0	35.25	0	3.20	0	23.46	0
C36		23942.28	20468.89	1274.08	6	127.08	1	60.63	0	1209.78	6
C37		34387.56	30150.86	1225.73	4	160.74	1	116.47	0	1044.97	3
C38		31226.08	2297.55**	574.19**	25**	151.81**	7**	0**	0**	444.31**	19**

Notes:

* Some data missing (Purcell Wilderness Conservancy)

** Some data missing (Private Land)

*** Some data missing (Cranbrook)

**** Some data missing (Height of the Rockies Provincial Park)

Deciduous Forest Summary by Landscape Unit

Golden Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
G01		48834.21	10304.17	64.24	1	8.89	0	43.31	0	12.04	0
G01P		24108.72	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
G02		24648.57	10839.00	130.39	1	95.35	1	35.03	0	0.00	0
G03		21200.65	9973.38	326.46	3	111.46	1	0.00	0	215.00	2
G04		17712.91	8181.09	121.83	1	4.68	0	67.34	1	72.97	1
G05		22047.79	10027.10	16.90	0	11.09	0	5.80	0	0.00	0
G06		26328.12	5365.82	18.21	0	0.00	0	0.00	0	18.21	0
G07		63977.46	14451.99	331.37	2	149.76	1	12.27	0	169.34	1
G08		31245.72	13156.38	1575.57	12	164.25	1	58.56	0	1470.79	11
G09		34192.93	8916.21	663.10	7	139.94	2	66.65	1	592.24	7
G10		59018.01	12784.83	117.84	1	0.00	0	107.35	1	10.50	0
G11		15568.67	5519.57	0.09	0	0.00	0	0.09	0	0.09	0
G12		26092.46	5139.35	84.40	2	84.40	2	0.00	0	0.00	0
G13		55975.00	15074.49	519.85	3	37.89	0	76.82	1	451.46	3
G14		23962.61	7448.74	529.58	7	50.48	1	44.38	1	529.36	7
G15		15911.41	9241.32	380.33	4	257.36	3	27.73	0	128.28	1
G16		34292.98	24224.15	9316.01	38	943.23	4	1116.15	5	8702.45	36
G17		20172.10	9250.07	1332.79	14	105.77	1	107.36	1	1119.68	12
G18		31355.53	6639.77	306.16	5	68.41	1	10.85	0	226.90	3
G19		51342.99	10919.17	1069.19	10	0.00	0	0.00	0	1069.19	10
G20		37446.28	26078.64	9508.54	36	1114.40	4	1015.61	4	9104.40	35
G21		69150.99	25283.22	3207.47	13	823.58	3	478.01	2	2584.65	10
G22		18646.08	12219.49	778.81	6	48.30	0	22.11	0	748.96	6
G23		44093.63	27733.17	8856.00	32	1115.42	4	375.73	1	8283.03	30
G24		12884.25	5123.89	27.98	1	0.00	0	0.00	0	27.98	1
G25		13153.40	8234.22	1951.47	24	212.04	3	132.27	2	1815.57	22
G26		34814.13	21039.03	2431.28	12	62.94	0	150.28	1	2364.44	11
G26P		120909.25	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
G27		12074.87	5862.90	471.82	8	0.00	0	0.00	0	471.82	8
G27P		8060.07	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
G28		32161.10	16280.72	1210.96	7	79.93	0	7.90	0	1210.96	7
G28P		8953.49	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
G29		23806.58	10016.99	118.81	1	47.06	0	35.35	0	115.47	1
PARK		87835.24	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data

Deciduous Forest Summary by Landscape Unit

Invermere Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
I01	Findlay	53812.30	18530.74*	384.14*	2*	108.18*	1*	13.69*	0*	262.27*	1*
I02	Buhl / Bradford	49134.62	34092.28	585.29	2	105.81	0	38.73	0	440.75	1
I03	Skookumchuck/Torrent	35516.30	29551.93	7097.94	24	338.12	1	1372.23	5	6339.82	21
I04	Premier/Diorite	43280.70	33854.16	1295.92	4	252.67	1	148.42	0	956.16	3
I05	Lussier/Coyote	55501.53	40714.77	1910.98	5	90.85	0	342.54	1	1649.18	4
I06	Blackfoot/Thunder	24372.22	13012.14	382.46	3	7.22	0	30.83	0	347.50	3
I07	East-Middle White	42762.82	24596.35	189.09	1	1.58	0	0.00	0	187.52	1
I08	North White	26791.86	15702.77	79.10	1	25.58	0	4.68	0	66.40	0
I09	Grave	32308.61	23227.28	1883.22	8	211.77	1	1317.39	6	893.07	4
I10	Nine Mile/Moscow	34977.41	27854.75	1038.23	4	21.79	0	545.88	2	564.90	2
I11	Kootenay	16759.56	12775.60	968.74	8	20.93	0	449.48	4	727.11	6
I12	Doctor/Fir	45920.95	31554.76	3453.07	11	110.38	0	446.97	1	3185.72	10
I13	East Columbia	20422.25	15672.05	974.93	6	155.73	1	148.83	1	760.54	5
I14	Brewer/Dutch	67421.71	36564.69*	1385.93*	4*	101.24*	0*	82.08*	0*	1228.44*	3*
I15	Toby	45286.66	19207.9*	1816.32*	9*	151.41*	1*	28.66*	0*	1684.95*	9*
I16	Jumbo	14548.13	5346.73	225.19	4	182.81	3	0.00	0	42.38	1
I17	Goldie	7651.31	5932.51	937.44	16	1.69	0	258.93	4	896.58	15
I18	Invermere	26046.99	17349.05	3126.01	18	335.50	2	364.32	2	3013.30	17
I19	Fenwick	18540.08	13278.66	151.85	1	0.00	0	134.24	1	31.41	0
I20	Palliser	42526.21	21072.79	1009.40	5	13.94	0	660.53	3	399.04	2
I21	Cochran	19933.61	10899.43	1128.64	10	39.65	0	495.80	5	672.83	6
I22	Albert	20792.26	10380.58	443.85	4	79.87	1	317.76	3	83.87	1
I23	Cross	84880.18	20563.99**	1304.96**	6**	58.63**	0**	992.12**	5**	741.19**	4**
I24	Pedley	21785.14	16781.29	1646.20	10	13.01	0	951.97	6	732.65	4
I25	Shuswap/Windermere	23249.54	16898.93	1186.04	7	221.06	1	324.33	2	889.72	5
I26	Horsethief	56015.63	19073.35	1722.32	9	716.97	4	78.17	0	1193.70	6
I27	Forster	16614.14	7939.30	117.06	1	9.65	0	20.72	0	87.20	1
I28	Frances	12265.74	5022.82	211.48	4	8.96	0	0.00	0	206.12	4
I29	Steamboat	33278.79	28136.08	6688.73	24	369.50	1	1442.27	5	6052.87	22
I30	Kindersley/Macauley	23488.01	15844.96	4670.25	29	337.50	2	306.12	2	4339.09	27
I31	Bugaboo	29679.70	12473.46	992.32	8	85.75	1	51.63	0	906.57	7
I32	Dunbar/Templeton	25211.36	14706.90	2232.76	15	266.33	2	227.15	2	2146.00	15
I33	Luxor	9289.27	6607.43	675.42	10	55.81	1	199.34	3	478.74	7
I34	Bobbie Burns	76807.08	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
I35	Lower Spillimacheen	26671.86	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
I36	McMurdo/Fraling	32222.17	19065.87	6943.64	36	482.02	3	1614.97	8	6530.76	34
I37	Upper Spillimacheen	47605.14	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
I38	Twelve Mile	10703.38	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
PARK	PARK	41456.11	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data

Notes

* Some data is missing (Purcell Wilderness Conservancy)

** Some data is missing (Kootenay National Park)

Deciduous Forest Summary by Landscape Unit

Kootenay Lake Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
K01		71467.44	53677.07	4868.08	9	421.77	1	1694.84	3	3552.99	7
K02		26344.51	22897.51	2492.68	11	236.12	1	133.89	1	2203.50	10
K03		42400.61	39096.87	2965.23	8	752.91	2	95.30	0	2209.41	6
K04		50103.29	38345.81	573.67	1	44.32	0	539.09	1	2.36	0
K05		34083.12	28755.08	1988.26	7	558.48	2	283.68	1	1347.17	5
K06		78224.42	60595.70	3906.14	6	403.37	1	736.74	1	3216.42	5
K07		40037.37	34805.56	3925.90	11	249.87	1	2473.67	7	1538.50	4
K08		43152.49	35600.10	8033.27	23	272.48	1	5920.97	17	3827.97	11
K09		41669.90	37485.79	5475.91	15	54.82	0	2345.93	6	4074.62	11
K10		53145.95	42254.96	5958.09	14	124.33	0	2683.33	6	3765.15	9
K11		23573.20	17803.49	2933.30	16	77.38	0	978.45	5	2388.38	13
K12		81984.18	56561.37	5797.19	10	34.05	0	2748.27	5	3586.28	6
K13		42454.09	12.15	10.30	85	9.62	79	3.35	28	0.10	1
K14		42349.92	27726.98	3038.58	11	135.75	0	2454.86	9	1186.18	4
K15		61800.10	24574.67	984.14	4	67.09	0	884.67	4	703.42	3
K16		39719.68	22879.50	1698.47	7	145.99	1	1396.15	6	460.05	2
K17		69437.36	39109.99	2958.41	8	1051.00	3	1271.70	3	1285.18	3
K18		48013.36	31384.53	4432.74	14	397.67	1	2995.75	10	2455.25	8
K19		7300.06	2.75	2.37	86	0.00	0	2.32	84	0.14	5
K20		38332.85	20294.32	3041.82	15	49.72	0	2633.77	13	990.83	5
K21		51895.89	23320.03	3472.37	15	133.51	1	2626.51	11	1376.15	6
K22		63178.24	24991.62	3505.00	14	562.72	2	2276.10	9	1180.44	5
K23		24018.43	7812.12	372.26	5	0.00	0	372.26	5	0.00	0
K24		53902.05	15254.94	36.73	0	6.26	0	30.47	0	0.00	0
K25		71567.35	45309.98	4426.14	10	933.64	2	1473.58	3	2681.39	6
K26		40617.42	26296.60	1684.73	6	235.90	1	968.70	4	782.55	3

Deciduous Forest Summary by Landscape Unit

Revelstoke Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
R01		34439.73	16671.79	883.96	5	163.91	1	639.23	4	191.78	1
R02		24229.71	18127.58	1932.46	11	143.79	1	1783.70	10	294.34	2
R03		60870.87	33780.67	9136.99	27	663.86	2	6754.38	20	4147.60	12
R04		28670.62	17963.47	3194.37	18	352.65	2	2564.82	14	994.10	6
R07		31423.11	14199.82	873.67	6	483.36	3	302.84	2	309.46	2
R08		16851.65	13997.82	1168.11	8	282.20	2	559.77	4	638.06	5
R09		11259.36	72.87	11.23	15	2.91	4	7.66	11	4.52	6
R10		46447.95	27376.07*	4023.93*	15*	170.06*	1*	2195.09*	8*	2737.37*	10*
R11		31323.52	10626.70	1329.58	13	233.61	2	938.98	9	335.44	3
R12		80966.11	41436.73	3186.02	8	550.66	1	2399.72	6	909.38	2
R14		44319.25	27459.46**	605.95**	2**	255.59**	1**	235.76**	1**	126.41**	0**
R15		55504.76	20870.19**	398.1**	2**	369.26**	2**	28.83**	0**	0**	0**
R16		57266.29	27164.72	542.16	2	469.55	2	97.78	0	34.72	0
R17		33868.96	19639.4**	445.01**	2**	14.82**	0**	414.19**	2**	164.42**	1**
R18		66658.83	33008.81**	233.02**	1**	154.8**	0**	78.22**	0**	14.52**	0**
R19		100906.75	47389.57**	2472.93**	5**	1363.54**	3**	1095.38**	2**	279.35**	1**
R20		99647.09	43773.19*	5592.96*	13*	916.81*	2*	2211.45*	5*	3346.68*	8*

Notes:
* Some data missing (Mt Revelstoke National Park)
** Some data missing (Private Land)

Deciduous Forest Summary by Landscape Unit

Robson Valley Forest District

Landscape Unit (LU)	LU Name	LU Area (ha)	Forest Area (ha)	Hardwood (ha)	Hardwood (%)	Cottonwood (ha)	Cottonwood (%)	Birch (ha)	Birch (%)	Aspen (ha)	Aspen (%)
RB01	FORGETMENOT	34869.37	20869.94	37.07	0	0.00	0	14.13	0	22.94	0
RB02	UPPER MORKILL	51640.48	27746.66	96.08	0	32.81	0	49.79	0	50.03	0
RB03	LOWER MORKILL/CUS	43836.97	25561.02	960.10	4	627.12	2	439.42	2	226.56	1
RB04	EASTTWIN-MCKALE	44857.41	19063.66	716.66	4	40.53	0	285.03	1	520.46	3
RB05	NORTHERN TRENCH	71043.78	62126.50	17470.24	28	7057.42	11	11572.46	19	9936.29	16
RB06	MILK	30774.38	18860.07	741.42	4	276.68	1	0.00	0	464.74	2
RB07	GOAT	34536.62	19963.98	914.94	5	672.32	3	37.09	0	215.45	1
RB08	BETTYWENDLE	14341.36	6616.23	17.92	0	17.92	0	0.00	0	0.00	0
RB09	CARIBOO	39919.04	12435.45	94.59	1	94.59	1	0.00	0	0.00	0
RB10	DORE	41657.44	11837.91	352.40	3	175.20	1	136.62	1	281.06	2
RB11	WESTTWIN	14622.39	7361.74	701.64	10	265.44	4	97.11	1	436.20	6
RB12	HOLMES	90150.80	34444.57	4973.69	14	226.33	1	1200.51	3	4345.31	13
RB13	HORSEY-SMALL	44789.99	14611.61	896.45	6	68.97	0	332.17	2	740.50	5
RB14	LOWERRAUSH	43509.91	14494.43	2144.20	15	474.58	3	585.51	4	1360.07	9
RB15	CASTLE	50421.47	16581.89	2818.49	17	579.68	3	1722.28	10	1151.85	7
RB16	UPPERRAUSH	56118.85	15023.94	742.19	5	15.70	0	42.27	0	688.49	5
RB17	KIWA-TETE	40883.00	11428.82	402.83	4	44.26	0	246.34	2	244.68	2
RB18	MCBRIDE-DUNSTER	69059.70	46466.79	25106.33	54	5758.89	12	8035.23	17	22862.19	49
RB19	CANOE	52027.68	16544.63	244.80	1	11.68	0	0.00	0	233.12	1
RB20	SWIFT CURRENT	9058.26	3136.50	333.93	11	29.12	1	18.46	1	306.07	10
RB21	SOUTHTRENCH	92100.84	62545.08	14206.75	23	1380.13	2	4201.21	7	13158.00	21
RB23	EAST KINBASKET	81059.75	35061.37	2116.34	6	331.32	1	721.58	2	1882.39	5
RB24	KINBASKET LAKE	12250.70	847.03	96.93	11	50.14	6	45.51	5	59.12	7
RB25	WEST KINBASKET	17411.02	8430.35	470.84	6	214.64	3	204.78	2	275.12	3
RB26	HUGH ALLAN	68200.44	28694.55	507.43	2	217.62	1	127.82	0	344.61	1
RB27	FOSTER	57831.98	22410.24	83.20	0	26.76	0	10.64	0	51.16	0
RB28	DAWSON	24338.26	8670.86	28.19	0	2.67	0	25.52	0	0.00	0
RB29	MOUNT ROBSON	220331.13	81540.72	4736.34	6	230.73	0	399.28	0	4437.27	5

APPENDIX IV. MANAGERS AND RESEARCHERS CONTACTED

CONTACTS	POSITION
Robson Valley	
Marc von der Gonna	Acting District Manager, BCFS
Chris Ritchie	Habitat Biologist, Prince George, WLAP
Revelstoke	
Dr. John Woods	Faunal Specialist, Parks Canada
Murray Peterson	Fire Specialist, Parks Canada
Del Williams	Operations Manager, Revelstoke Community Forest
Dr. B. McLellan	BCFS Research
Golden	
D'Arcy Monchak	Planner, BCFS
Bob Richkum	Zone officer, BCFS
Dave Clapperton	Zone silviculturalist, BCFS
Invermere	
Gail Berg	Range Ecologist, BCFS
Greg Anderson	Operations Manager, BCFS
Alan Dibb	Parks Canada, Radium Hot Springs
Rob Walker	Parks Canada fire specialist
Larry Ingham	CBFWCP, Invermere
George Richardson	TEMBEC, Parsons
Cranbrook	
Oliver Thomae	Operations Manager, BCFS
Tom Volkers	Planner, BCFS
Dennis Petryshen,	Silviculture, BCFS
Steve Byford	Small Business, BCFS
Rob Neil	Planning, WLAP
Peter Davidson	FES, Cranbrook
Mike Gall	Resource manager, Provincial Parks
Reg Davis	Interior Reforestation
Greg Allen	Paleoecologist and botanist
Kootenay Lake	
Mike Knapik	Forest Ecosystem Specialist, WLAP
Jim Smith	Manager, Creston Community Forest

Arrow

Pat Field	Operations Manager, BCFS
Rob Serrouya	Consultant
Paul Jeakins	Consultant, managing IFPA

Nelson

Bruce Fraser	Regional Manager – Silviculture, BCFS
Mike Madill	Regional Reforestation Forester, BCFS
Cal Hauk	Regional Manager – Inventory, BCFS
Don Gayton	SIFERP

Outside the region

Suzanne Simard	BCFS Research, Kamloops
Dr. Jeff Braatne	Research ecologist, Seattle
Ray Demarchi	Consultant
Carol Hartwig	Consultant
Jon Shepherd	Lepidoptera expert
Bob Churchill	Consultant, Fort St. John