Backlog forest land rehabilitation in the SBS and BWBS zones in the northern interior of British Columbia
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by
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References to the B.C. Ministry of Forests and Lands appear throughout this report. This reflects the name of the Ministry from August, 1986 through July, 1988.
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1 INTRODUCTION

This report examines the nature and extent of "backlog NSR", and the techniques used to treat it in the northern interior of British Columbia. The term "backlog NSR" (not satisfactorily restocked) refers to forest land which could be fully stocked with silviculturally acceptable trees but is not, and is not likely to be without intensive rehabilitative treatment.

The report is one outcome of FRDA Project 1.15, entitled "A Problem Analysis of Backlog Forest Lands." The objectives were to examine all aspects of rehabilitation; undertake a review of relevant literature; identify existing practices and perceptions; list successful and unsuccessful treatments; classify backlog types; and develop prescriptions.

1.1 Study Area

The geographic focus of the report is the Sub-boreal Spruce (SBS) and the Boreal White and Black Spruce (BWBS) zones, within the Prince George and Prince Rupert Forest Regions and the Quesnel Timber Supply Area (TSA) in the Cariboo Forest Region (Fig.1). The study area is larger than one-third the size of the province (an estimated 375 000 km²).

FIGURE 1. Location of study area.
1.2 Methods of Investigation

The subject of backlog forest land was examined to determine the problems of clearing sites of existing vegetation and then of preparing them for the successful establishment of commercially valuable species. Examination took the form of field tours and site assessments, interviews, questionnaires, and a literature review.

As part of the fieldwork, 40 sites, exemplifying successful and unsuccessful silvicultural practices, were visited. In each, a detailed ecosystem description, including soils and competing vegetation, was carried out. The silvicultural history of the block was reconstructed as accurately and completely as possible. Of these 40 sites, 25 were selected as "case studies" and are summarized in this report to illustrate some of the points made in the text. A much larger number of sites were visited, but not described in the same detail. Several sites highlight particular problems in site rehabilitation or microsite preparation and provide another source of information for this report.

In addition to visiting field sites, the author toured the study area to interview licensee and Forest Service silviculturists. All aspects of regeneration and rehabilitation practices were examined. A questionnaire was also sent out to 55 experienced silviculturists, currently specializing in regeneration and/or rehabilitation. Thirty-four responded.

All sources of information were synthesized to produce an account of rehabilitation practices (Chapters 4 and 5). Sources are indicated in the text as personal communication, questionnaire response, case study, observation, or literature reference.

1.3 Organization of the Report

Chapter 2 provides an overview of ecological factors and their silvicultural implications. Although the study area in general has a continental climate distinguishing it from other areas in British Columbia, such generalizations obscure a wide range in precipitation, snow accumulation, soil temperature, soil moisture deficit, and other ecological factors. Differences in any of these factors may have a significant effect on rehabilitation.

Chapter 3 introduces an interim classification of backlog vegetation types observed in the field. It also defines NSR backlog and gives estimates of its extent in the study area.

Chapters 4 (Brush Clearance) and 5 (Microsite Preparation) describe rehabilitation methods that are or have been practised. The review was organized this way because rehabilitation is viewed as consisting of two "phases" (Fig. 2). First, the backlog site must be cleared of brush. Second, biologically suitable microsites must be created in preparation for planting. In some cases, microsite preparation will accomplish a suitable degree of brush clearance; in others, microsites will be created during the course of brush clearance.

Appendix 1 presents a synopsis of 24 case studies. In each one, the site history, treatment impact, and degree of brush competition is summarized. Treatment success is then assessed, and implications for rehabilitation discussed.

The questionnaire is reproduced in Appendix 2, and review of the response is presented. Appendix 3 contains a list of contacts made during the project.
FIGURE 2. Two phases of rehabilitation.
2 CLIMATE AND SOIL

2.1 Biogeoclimatic Units

The study area for this report consists of the Boreal White and Black Spruce and Sub-boreal Spruce zones within the Prince George and Prince Rupert Forest Regions and in the Quesnel TSA of the Cariboo Forest Region. This embraces about 25 biogeoclimatic units and, as such, there is considerable variation from north to south and east to west.

Biogeoclimatic units represent an integration of climate, vegetation and soils (Krajina 1969). Some units differ from others in climatic characteristics that are important for regeneration. Within the limits of the available data base, these characteristics and differences are discussed in the following report sections.

Statements regarding the climate of subzones and variants (Tables 1 and 2) are based on normalized data for the 30-year period, 1951-1980 (AES 1982), on data presented by McLeod and Meidinger (1985), and on unpublished data from McLeod (pers. comm.). Most current data on climate are in the form of averages, such as mean annual air temperature or mean growing season (May to September) temperature. Averages can be useful, but in some cases extreme values, the sequence of events (such as rainfall and warm weather), or the degree of variability itself may be of most importance.

### TABLE 1. Climatic data for selected stations in the SBS zone

<table>
<thead>
<tr>
<th>Station</th>
<th>Unit</th>
<th>Group</th>
<th>Mean annual temperature</th>
<th>Mean summer temperature</th>
<th>Rainfall (mm)</th>
<th>Snowfall (mm w.e.)</th>
<th>Days without frost</th>
</tr>
</thead>
<tbody>
<tr>
<td>McGregor</td>
<td>fl1</td>
<td>1</td>
<td>3.5</td>
<td>12.5</td>
<td>620</td>
<td>328</td>
<td>162</td>
</tr>
<tr>
<td>Aleza Lake</td>
<td>j1</td>
<td>1</td>
<td>3.0</td>
<td>12.4</td>
<td>558</td>
<td>339</td>
<td>155</td>
</tr>
<tr>
<td>Topley Ldg.</td>
<td>e1</td>
<td>2</td>
<td>2.5</td>
<td>11.3</td>
<td>286</td>
<td>246</td>
<td>156</td>
</tr>
<tr>
<td>Fort Babine</td>
<td>e1</td>
<td>2</td>
<td>1.2</td>
<td>10.2</td>
<td>340</td>
<td>261</td>
<td>126</td>
</tr>
<tr>
<td>Prince George A</td>
<td>e2</td>
<td>3</td>
<td>3.3</td>
<td>12.2</td>
<td>410</td>
<td>242</td>
<td>170</td>
</tr>
<tr>
<td>Burns Lake</td>
<td>e2</td>
<td>3</td>
<td>2.2</td>
<td>11.2</td>
<td>281</td>
<td>185</td>
<td>159</td>
</tr>
<tr>
<td>Kalder Lake</td>
<td>e2</td>
<td>3</td>
<td>2.2</td>
<td>9.5</td>
<td>348</td>
<td>356</td>
<td>126</td>
</tr>
<tr>
<td>Fort St. James</td>
<td>k3</td>
<td>4</td>
<td>2.3</td>
<td>11.7</td>
<td>290</td>
<td>204</td>
<td>150</td>
</tr>
<tr>
<td>Quesnel</td>
<td>l</td>
<td>4</td>
<td>5.0</td>
<td>14.0</td>
<td>365</td>
<td>166</td>
<td>182</td>
</tr>
<tr>
<td>Alexis Creek</td>
<td>a</td>
<td>5</td>
<td>4.0</td>
<td>8.9</td>
<td>270</td>
<td>195</td>
<td>75</td>
</tr>
<tr>
<td>Tatilkuz Lk.</td>
<td>a</td>
<td>5</td>
<td>M&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.1</td>
<td>312</td>
<td>197</td>
<td>M</td>
</tr>
<tr>
<td>Punctchesakut Lk.</td>
<td>a</td>
<td>5</td>
<td>2.5</td>
<td>11.4</td>
<td>349</td>
<td>176</td>
<td>152</td>
</tr>
</tbody>
</table>

<sup>a</sup> May to September inclusive.

<sup>b</sup> w.e.: refers to water equivalent.

<sup>c</sup> Missing data.
2.1.1 The Sub-boreal spruce zone

This zone has a continental climate with long, cold winters and short, moist summers. The SBS exhibits an annual range of mean monthly temperatures of about 25°C, much more than that on the coast, but less than in the BWBS (Schaeffer 1978). The SBS is somewhat less continental than the BWBS, with slightly milder winters and cooler summers, but its extreme minimum temperatures are nearly as low.

Precipitation is greatest in the easternmost biogeoclimatic units, due to orographic lifting of moist eastward-moving air masses as they approach the Rocky Mountains. Westerly subzones are in the rain shadow of the Coast Mountains, although this effect diminishes towards the east.

In general, mean annual and growing season temperatures decrease with increasing latitude and elevation. Paralleling this decrease are changes in proportion of total precipitation falling as snow, date of snowmelt, length of growing season, and growing degree days. The combination of varying temperature and precipitation regimes results in a complexity of macroclimates across the SBS zone.

To simplify this complexity, biogeoclimatic units with similar macroclimatic characteristics have been combined into five broader “Groups”. These groupings were based on the suggestions from the staff of the Ecology Program of the B.C. Ministry of Forests and Lands, and contain units that are not necessarily contiguous. Readers should refer to biogeoclimatic maps of the Prince George Forest Region (McLeod and Meidinger 1985), Prince Rupert Forest Region (Pojar et al. 1984), and Cariboo Forest Region (Research Section, unpublished data).

Group 1. “Wet, devil’s club units” (SBS1, 2, f, and n)

These are the easternmost biogeoclimatic units of the SBS, lying on or near the western slopes of the Rocky Mountains. The two selected stations in Table 1 receive about 900 mm of total precipitation (rain and snow) per year. Within this group, total annual precipitation ranges from 542 to 1635 mm (McLeod and Meidinger 1985).

The biogeoclimatic units in this group experience heavy snowfalls. Deep snow limits the depth of soil freezing by insulating the soil. It may also cause limb breakage in susceptible species, particularly lodgepole pine. Wet snow in particular weighs heavily on trees and restricts maneuverability of machines. Snow affects options for backlog rehabilitation, both by physically limiting machine operation and access, and by reducing the depth of soil freezing. This latter effect can be a problem on some sites where frozen soil is necessary for machine access.

The relatively heavy rainfall in these units has numerous silvicultural implications. Soil moisture deficits are likely to be less pronounced and of shorter duration than in areas further west. Since summers are relatively moist in this group, obtaining adequate duff reduction from a prescribed burn can be difficult. Summer burning may be necessary to achieve target impacts on many sites (depending, of course, on soil, terrain and fuel characteristics as well).

The generally wetter conditions lead to relatively heavy vegetative covers and, on some sites, colder soils. In the SBS1, for example, devil’s club (Oplopanax horridus) is a member of mesic ecosystems (DeLong et al. 1986), whereas in drier subzones, this plant is normally confined to subhygric ecosystems. Greater moisture availability allows more vigorous brush competition than in drier subzones to the west, such as the SBSd. While soil temperature and brush competition are problems throughout the SBS zone, they are particularly difficult in Group 1.

Group 2. “Snowy, spruce-balsam units” (SBS1, e1, and m)

These are fairly cool units, in which a relatively high proportion of the total precipitation falls as snow. Total precipitation ranges from 437 to 922 mm (McLeod and Meidinger 1985).
In the Prince Rupert Forest Region, the SBSes1 is distinguishable from other SBS units in that it contains subalpine fir (Abies lasiocarpa). As well, it is the wettest and snowiest of the Forest Region's three subzones (SBSes1, d, and a). Tree productivity is greater in the SBSes1 (Pojar et al. 1984), partly because it is moister than the SBSesd and warmer than the SBSes. The SBSes1 extends into the Cariboo and Prince George Forest Regions, whereas the SBSes is confined to higher elevations in the southwestern part of the Prince George Forest Regions. The SBSesm is confined to isolated high elevations east of the Fraser River, surrounded by the SBSkes subzone at lower elevations.

The silvicultural implications of Group 2 climate are similar to those of Group 1. The Group 2 climate is neither as moist nor as snowly as the Group 1 climate, but is moister and snowier than other groups. Consequently, soil moisture deficits are likely to be less pronounced than in adjacent Group 4 units; and soils will warm more slowly because of somewhat heavier snow accumulation and later snowmelt. Mean summer and annual temperatures are not consistently different from other groups.

Group 3. “Spruce-balsam, shrubby units” (SBSc, d, e2, and o)

These units are relatively mild with moderate amounts of precipitation. They are less snowy than Group 2 units, with consequently earlier snowmelt and soil warming in the spring, and slightly longer growing seasons.

In the Prince Rupert Forest Region, the SBScd is regarded as intermediate between the SBSc and e1 units, being moister and warmer than the SBSc (Group 5), but drier and warmer than the SBSe1 (Group 2) (Pojar et al. 1984).

This group contains units dispersed across the zone. The SBSo (‘dry, cold’) lies on the shores of Williston Lake, near the foot of the Rocky Mountains. Despite its proximity to Group 1 units, it receives a modest amount of precipitation, ranging from 467 to 671 mm (McLeod and Meidinger 1985). The SBSe2 (‘moist, cool’) occupies mostly rolling or flat, low-elevation country northeast of Prince George (as well as a narrow salient to the southeast). Both the SBSe2 and o units are confined to the Prince George Forest Region.

The SBSc (‘moist, central’) receives a similar range of precipitation as the SBSe2 and the o, but is somewhat warmer (although considerable overlap is present between the SBSc and e2). The SBSc subzone occupies a limited area west of the Fraser and Quesnel rivers in the southern Prince George and northern Cariboo Forest Regions.

The SBScd (‘dry, cool central’) is the driest unit in Group 3, and lacks subalpine fir. The SBScd has its greatest extent in the southern portion of the Prince Rupert Forest Region, where it is extensive throughout lower elevations. It does not extend into the Cariboo Forest Region. Soil moisture deficit is probably most pronounced in this subzone. According to Pojar et al. (1984), the SBScd experiences a longer and warmer growing season than the adjacent subzones in the SBSk. Snowmelt and soil warming usually take place earlier.

In general, Group 3 units are neither as cold as Group 5, nor as warm as Group 4 units (with the exception of the SBSc).

Group 4. “Warm, valley units” (SBSk1, k2, k3, h, and I)

The units in Group 4 are characterized by generally high mean annual and growing season temperatures (Table 1) and a large number of growing degree days (McLeod and Meidinger 1985). There is considerable overlap in temperature and precipitation between Group 4 units and those of other groups. Circum-mesic ecosystems in this unit frequently contain Douglas-fir (Pseudotsuga menziesii), probably reflecting the warmer conditions.
The SBSk subzone ("dry, warm, southern") extends over relatively low elevations from Stuart Lake in the Prince George Forest Region, south and southeast to Quesnel and Horsefly in the Cariboo Forest Region. To the south, it grades into the IDF zone.

The climate at Fort St. James (Table 1) is more northerly (and thus cooler) than the bulk of the area within the SBSk subzone. In general, the SBSk experiences a relatively warm climate with moderate precipitation. Although growing seasons are likely to be longer here than in adjacent, higher elevation (Group 2) subzones, productivity may be limited by soil moisture deficits.

The SBSI ("dry, warm, central") is the warmest subzone in the SBS, with mean annual and summer temperatures of 4.3 and 13.3°C, respectively (McLeod and Meldinger 1985). Growing degree days are similarly higher (averaging 1349) and "days without frost" more frequent (Table 1: Quesnel).

Group 5. "Dry, pinegrass-moss units" (SBSa and b)

These units are the driest in the zone (with the exception of the SBSd); they also have the lowest summer mean temperatures and the lowest growing degree day totals (A. McLeod, unpublished data).

In the Prince Rupert Forest Region, the SBSa ("pine-spruce subzone") has the driest and coldest climate in the SBS (Pojar et al. 1984). It extends from the extreme southern portion of the Prince George Forest Region into the Cariboo, where it is extensive west of the Fraser, and subdivided into three variants. As in the Prince George Forest Region, the SBSa is regarded as having relatively low productivity (Annas and Coupe 1979), due both to low temperature and rainfall. Existing forests commonly consist of even-aged lodgepole pine which has developed following wildfires. Rehabilitation of these forests has been a low priority because of low productivity.

The SBSb ("dry, cool, southern") was seen by Annas and Coupe (1979) as transitional between the "more typical sub-boreal forests" to the north and the IDF zone to the south. The subzone contains Douglas-fir, which it shares with Group 4 units; but its mean annual and summer temperatures are lower in the SBSb than in the units of Group 4.

2.1.2 The Boreal white and black spruce zone

This zone experiences a northern, continental climate, with long, cold winters and short, relatively warm summers (Annas 1983). It has the most continental climate in the province, with an annual range of mean monthly temperatures greater than 30°C over much of the area, and up to 40°C in the northeastern corner (Schaeffer 1978).

Mean annual temperatures are just above 0°C over most of the area (Table 2), falling below freezing in the Fort Nelson area (BWBSa1) and in the northern Rocky Mountain trench area (BWBSa2), (McLeod and Meldinger 1985). These means are lower than in the SBS zone, reflecting the severe winter temperatures, especially during the frequent incursions of arctic air masses. The extreme minimum temperature recorded at Fort Nelson between 1951 and 1980 was -51.7°C (AES 1982), one of the lowest recorded in the province. Mean growing season temperatures (May to September, inclusive) range from 11.9 to 12.5 in the BWBSa1 ("moist, cool, southern") variant (Table 2). They are lower in the BWBSd ("moist, cold") and e ("Cordilleran") subzones. The BWBSa1 (“Fort Nelson lowland, northern”) has warm summers with a mean temperature of 12.8°C. This variant has a greater number of growing degree days (1262) than other units in the zone, because of long summer days.
TABLE 2. Climatic data for selected stations in the BWBS zone

<table>
<thead>
<tr>
<th>Station</th>
<th>Unit</th>
<th>Mean annual temperature</th>
<th>Mean summer temperature&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Rainfall (mm)</th>
<th>Snowfall&lt;sup&gt;b&lt;/sup&gt; (mm w.e.)</th>
<th>Days without frost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort St. John</td>
<td>c1</td>
<td>1.3</td>
<td>12.5</td>
<td>289</td>
<td>222</td>
<td>172</td>
</tr>
<tr>
<td>Dawson Creek</td>
<td>c1</td>
<td>1.9</td>
<td>11.9</td>
<td>282</td>
<td>181</td>
<td>153</td>
</tr>
<tr>
<td>Hudson Hope</td>
<td>c1</td>
<td>1.9</td>
<td>12.3</td>
<td>247</td>
<td>194</td>
<td>161</td>
</tr>
<tr>
<td>Chetwynd</td>
<td>c1</td>
<td>2.0</td>
<td>12.4</td>
<td>268</td>
<td>168</td>
<td>164</td>
</tr>
<tr>
<td>Pink Mountain</td>
<td>d</td>
<td>-1.5</td>
<td>9.9</td>
<td>336</td>
<td>211</td>
<td>143</td>
</tr>
<tr>
<td>Beatton R.</td>
<td>d</td>
<td>-1.2</td>
<td>10.5</td>
<td>298</td>
<td>195</td>
<td>133</td>
</tr>
<tr>
<td>Ware</td>
<td>e</td>
<td>-0.6</td>
<td>10.5</td>
<td>301</td>
<td>187</td>
<td>122</td>
</tr>
<tr>
<td>Ingenika Pt.</td>
<td>e</td>
<td>0.5</td>
<td>11.4</td>
<td>307</td>
<td>184</td>
<td>M&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fort Nelson</td>
<td>a1</td>
<td>-1.4</td>
<td>12.8</td>
<td>299</td>
<td>187</td>
<td>146</td>
</tr>
</tbody>
</table>

<sup>a</sup> May to September inclusive.

<sup>b</sup> 'w.e.' refers to water equivalent.

Missing data.

The BWBS<sup>1</sup>c1 variant, which is of particular interest to this report, has an average Growing Degree Day value of 895, based on 15 stations (McLeod and Meldinger 1985). Fort St. John receives over 2000 hours of bright sunshine per year, more than any other interior station in British Columbia (Schaeffer 1978).

Table 2 shows that “days without frost” generally decrease in number from south to north, reflecting the shorter growing season. However, because incidence of frost is highly sensitive to local conditions, variability within biogeoclimatic units can be high. Frosts can occur in any month, except at Fort Nelson and Fort St. John, where July frosts were not recorded (AES 1982).

The very low winter temperatures east of the Rocky Mountains can be interrupted by incursions of adiabatically warmed air from the west (“Chinooks”). This is reflected in the extreme maximum January or February temperatures recorded east of the Rockies (Fort Nelson: 8.5°C; Fort St. John: 10.6°C; Chetwynd: 10.0°C) compared to stations west of the Rockies (Ware: 3.9°C; Ingenika Point: 5.6°C). Chinooks can last several days, and can damage seedlings by promoting transpiration from frozen soils.

Precipitation is relatively even over the BWBS zone, ranging from 456 mm at Chetwynd to 547 mm at Pink Mountain (Table 2). About a third of this falls as snow. Total precipitation peaks during the summer months, usually taking the form of convection rainfall. Despite this, long days, high insolation, consistent winds, and relatively warm summer temperatures can produce moisture deficits during the latter part of the growing season. According to Schaeffer (1978), summer moisture deficits of 150 mm have been estimated to occur at lower elevations. Late snowmelt, short growing seasons, and soil moisture deficits combine to make planting windows very narrow in the BWBS zone.

Table 3 summarizes the climatic characteristics in each of the groupings of biogeoclimatic units discussed above. Each parameter, estimated or derived from normalized climatic data (AES 1982, 1984), is ranked on a relative scale within the study area (consisting of both zones). These rankings show that within units or groupings of units, variation may be high. Group 3 in the SBS, for example, exhibits considerable variation in most parameters (reflecting its wide latitudinal range). Many of the parameters are site-dependent; that is, they will vary according to surface or topographic features. For example, winter minimum temperatures and frost-free period will be lower in topographic lows or on north-facing slopes. Similarly, snowpack depth and duration are highly dependent on surface features, such as size and orientation of opening, aspect and slope.
### Table 3. Summary of climatic characteristics and forestry interpretations

#### Biogeoclimatic Unit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BWBS</th>
<th>SBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>Growing Degree Days</td>
<td>High</td>
<td>Mod.</td>
</tr>
<tr>
<td>Mean Summer Temp. (May to Sept. inclusive)</td>
<td>Mod. to High</td>
<td>V. Low to Low</td>
</tr>
<tr>
<td>Mean Summer Precip. (May to Sept. inclusive)</td>
<td>Mod.</td>
<td>High to V. High</td>
</tr>
<tr>
<td>Soil Moisture Deficit</td>
<td>High</td>
<td>V. Low to Low</td>
</tr>
<tr>
<td>Winter Minimum Temperature</td>
<td>V. Low to Mod.</td>
<td>V. Low to Mod.</td>
</tr>
<tr>
<td>Winter Maximum Temperature</td>
<td>Mod.</td>
<td>Mod.</td>
</tr>
<tr>
<td>Snowfall</td>
<td>Low to Mod.</td>
<td>Mod.</td>
</tr>
<tr>
<td>Snow Duration</td>
<td>Short to Mod.</td>
<td>Mod.</td>
</tr>
<tr>
<td>Frost Free Period</td>
<td>Mod. to Long</td>
<td>Short to Mod.</td>
</tr>
<tr>
<td>Planting Window (spring/summer)</td>
<td>Short to Mod.</td>
<td>Long to V. Long</td>
</tr>
</tbody>
</table>

**Notes:**
1. All interpretations are relative to other biogeoclimatic units within the SBS and BWBS zones.
2. Italicized characters are inferred from estimated parameters.
3. Moisture deficit is inferred from summer precipitation and temperature. It assumes a mésic, well-drained site.
4. Planting window is inferred from snow duration and soil moisture deficit. It assumes planting may begin shortly after snowmelt and continue until the onset of a soil moisture deficit.
5. Snow duration is estimated from snow survey (Water Management Br. 1965) and climatic data (AES 1982).
6. Definitions of classes are as follows:
   - **Very (V.) High or Long:** greater than (mean of 21 stations plus one standard deviation).
   - **High or Long:** between one-half and one standard deviation above the mean.
   - **Moderate (Mod.):** within one-half and one standard deviation of the mean.
   - **Low or Short:** between one-half and one standard deviation of the mean.
   - **Very (V.) Low or Short:** less than (mean of 21 stations minus one standard deviation).
2.2 Soils

In this section, broad soil types, classified by parent materials, are briefly described, together with pertinent silvicultural implications. Because of the vast area covered in this report, detailed descriptions are not appropriate. For specific soil survey reports, the reader is referred to Cotic and van Barneveld (1974) for the Nechako-Francois Lake area; Kelley and Farstad (1946) and Kesler et al. (1973) for the Prince George area; Runka (1972) for the Smithers-Hazelton area; Vold (1977) for the northeast coal area; Valentine (1971) for the Fort Nelson area; and Lord and Mackintosh (1982) for the Quesnel area.

2.2.1 Morainal soils

Morainal material, or till, is the most widespread parent material throughout the study area. In most of the interior plateau, the subdued topography is mantled with varying thicknesses of morainal material. In low-lying valleys and basins, this till may be buried under lacustrine or deltaic deposits. Morainal deposits usually take the form of “blankets”, which cover the underlying bedrock surface without obscuring its shape. Surface expression may also take the form of deeper till plains, which may be drumlinized, fluted or kettled.

Morainal material is variable, generally poorly sorted and unstratified. In the study area, most morainal soils exhibit a sandy loam to silty loam texture at the surface, grading to loams or clay loams with depth. Coarse fragment contents normally range from 10 to 40% and consist largely of gravel.

Soils developed on till are usually Orthic Gray Luvisols, grading to Brunisolic Gray Luvisols with increasing moisture. Dystric Brunisols may form in coarser-textured tills. Humo-ferric Podzols are present in the wettest climates, such as the SBSF subzone.

Gray Luvisols are the predominant soil throughout the study area. They have a slightly acid Ae horizon ranging from about 10 to 40 cm thick. Beneath this, a clay-enriched Bt horizon is frequently impenetrable to seedling roots. Consequently, it forms an inappropriate rooting medium. Scalping of the overlying, more friable Ae horizon and planting directly into the Bt horizon will probably result in high seedling mortality and/or poor growth.

Because the Ae horizon contains little incorporated organic matter, it is poor in nutrients, particularly nitrogen, phosphorus and sulphur. For best growth, seedling roots need to tap pockets or layers of soil enriched in organic matter. Thus, mixing or inverting treatments, which conserve organic matter, are most appropriate from the point of view of nutriet supply.

2.2.2 Lacustrine soils

Lacustrine parent materials are common in valleys and basins where pro-glacial lakes formed. They are extensive in three areas: (1) around Fort St. James, Vanderhoof and Prince George; (2) around Williston Lake; and (3) throughout the Peace River basin. Smaller valleys and basins may also contain lacustrine sediments.

These deposits are generally flat or gently undulating, unless they are very shallow, in which case they may simply blanket the underlying bedrock or till. Dissection by rivers and streams has changed the original form in some locations.

Soils are Gray Luvisols, with textures ranging from silt to clay loam and even heavy clay. Lacustrine soils frequently exhibit a clay-enriched Bt horizon which has unfavorable physical properties, as do the Bt horizons in morainal soils. Many of these soils are poorly or imperfectly drained because of the impervious nature of the subsoils. It has been estimated that about 250 000 ha of fine-textured, poorly drained soils of this type are present in the central Interior (Grevers and Bomke 1986).
Lacustrine soils are difficult to manage. Because of their fine texture and subdued topography, soil moisture levels are generally high in the spring, especially during and following snowmelt. Thus, although machine operation is not limited by terrain or stoniness, the soils cannot support heavy traffic during spring. Mechanical site preparation treatments must be carefully timed to avoid soil degradation. In addition, brush competition has been identified as a problem on these soils (e.g., Cotic and Van Barneveld 1974). For optimum production of agricultural crops or tree seedlings, these soils require tillage designed to decrease surface moisture and increase soil temperature, as well as to control weeds. Grevers and Bomke (1986) found that moldboard ploughs were more effective in achieving these goals than were chisel or disc plowing.

The Gray Luvisols developed on lacustrine materials in the BWBS zone resemble those west of the Rockies, except that the Bt horizon is less easily distinguished (Green and Lord 1978). Saturation during the spring may lead to the formation of mottling in some profiles. Competition from reedgrass (*Calamagrostis* spp.) is a particularly serious problem on these lacustrine soils. Tillage treatments to improve soil temperature and moisture regimes must also set back reedgrass, and incorporate its thatch.

### 2.2.3 Fluvio-glacial and fluvial soils

Fluvio-glacial materials were deposited by glacial meltwater in various parts of the study area, but are not as extensive as morainal and lacustrine soils. Deposits take the form of terraces, esker complexes, or deltas. Terraces are common along the major river valleys, such as the Fraser, Nechako, MacGregor, and Bowron rivers. Deltaic deposits of sand and gravelly sand can be found at various locations along the margins of lacustrine deposits.

Fluvio-glacial parent materials are commonly coarse-textured, ranging from sands to gravels; derived soils are thus well or rapidly drained. Soils are usually Dystric Brunisols or Humo-ferric Podzols in wetter climates. Because of their low moisture-holding capacity, fluvio-glacial soils are usually associated with lodgepole pine stands. On lower slopes and receiving sites, these coarse-textured soils may also be productive for white spruce.

Silvicultural implications of fluvio-glacial soils include their potential for serious moisture and nutrient deficiency. Because of the generally shallow nature of the duff layers (which is important both for nutrient and moisture retention) fluvio-glacial soils have a high sensitivity to prescribed burning. Recommended stock types are those with high root/shoot ratios (e.g., Pojar *et al.* 1984). Brush competition and frost-heaving are generally not major problems on most fluvio-glacial soils (unless in receiving sites). Stoniness may be a slight limitation to mechanical site preparation on some very gravelly outwash materials, but terrain and trafficability are normally conducive to machine operation (with the exception of terrace scarps). Site preparation commonly takes the form of dragging.

Fluvial soils are developed on modern (i.e., post-glacial) floodplains, which may or may not be actively building. They commonly contain high proportions of silt and fine sand, and are productive for both tree growth and agricultural crops. Many such soils have been converted to agriculture. Surface expression and trafficability are, in general, conducive to mechanical treatments, unless water tables are high. In the BWBS, some of the most productive stands of white spruce are on alluvial soils, interspersed between river meanders. Easy access to these sites is therefore limited to the winter, when rivers are frozen.

Silvicultural constraints on fluvial soils include frost-heaving, low soil temperatures, and heavy brush competition.
2.2.4 Organic Soils

Organic soils occur in small isolated areas throughout the SBS zone, usually occupying depressions. In the BWBS zone, they are extensive in the Fort Nelson area, especially where drainage is impeded by shale beds (Valentine 1971). These soils are associated with poor drainage, high water tables, and poor aeration - conditions necessary for the accumulation of organic material.

Veneers of organic matter between 20 and 100 cm are commonly associated with spruce-horstail ecosystems, identified in most SBS units (e.g., DeLong et al. 1986). Whether organic soils (as defined by the Canada Soil Survey Committee 1978), or merely veneers over mineral soil, these soils are difficult to manage. Trafficability is poor, and organic horizons may be too deep for mounds to use mineral soil as a capping. They are also subject to low soil temperatures (being slow to warm in the spring), heavy brush competition, and restricted options for mechanical site preparation. Frequently the soils are treated by ripper ploughs during the winter, when they are frozen. Even then, a high water table may remain a problem.

2.3 Soil Climate

2.3.1 Soil temperature

Silviculturists generally perceive low soil temperature (along with brush competition) to be the most serious ecological constraint to regeneration in the northern Interior (see Appendix 4). Most of the soils in the study area fall into the "Cold Cryoboreal" soil temperature class (Lavkulich and Valentine 1978). In general, soils in the SBS and BWBS zones have mean annual temperatures (at 50 cm depth) between 2 and 6°C.

Soil temperatures for soil climate classification are taken at 50 cm to avoid diurnal fluctuations (Black 1982), but temperatures at shallower depths are more important silviculturally. Figure 3 shows the annual pattern of soil temperatures for depths of 5 and 10 cm at Prince George, Beaverlodge and Fort Vermillion (representing the SBS2e, the BWBS1c, and the BWBSat1, respectively). The data represent 30-year normals under a short grass cover (AES 1984). Thus, although the curves do not represent soils under forest cover, they are fairly representative of recently denuded sites.

At Prince George (Fig. 3), the soil is frozen at 5 cm between late December and late March on average. The depth of frost extends beyond 20 cm but not to 50 cm.

At Beaverlodge in Alberta, across the border from Dawson Creek, soils are frozen between early November and early April, and freezing extends below 50 cm but not to 100 cm. This reflects the more severe winters in the BWBS compared to the SBS. The Beaverlodge station has a mean annual soil temperature at 5 cm of 4.7°C, compared to 6.6°C at Prince George.

Fort Vermillion, in northern Alberta, has roughly the same mean annual soil temperature as Beaverlodge, despite its more northerly location. Summer soil temperatures are considerably higher than at Beaverlodge or Prince George, reflecting the more continental climate and longer days.

At Prince George, soil temperatures exceed 5°C in early May at 5 cm depth and in late April at 10 cm. The 20 to 25°C optimum for white spruce root growth (R. McMinn, pers. comm.) is rarely attained before July. Mean afternoon temperatures in July reach 19.3°C at 5 cm at Prince George, 18.3°C at Beaverlodge, and 24.1°C at Fort Vermillion.

The soil temperatures described here are for only one soil type in each station. Soil temperature regimes depend on soil and site factors such as soil moisture, organic matter content, texture, porosity, duff thickness, aspect, and degree of shading, in addition to the prevailing climate. Mean annual soil temperatures are usually well correlated with mean annual air temperatures (within macroclimatic
regions), but the degree and pattern of fluctuation about the mean are subject to local conditions. For example, a dry mineral soil will experience a greater annual temperature range than a moist mineral or organic soil. It will cool to a lower temperature during winter, but will warm faster in the spring. Wet soils are cold soils, primarily because of the high heat capacity of the soil water.

![Graphs showing soil temperature variations at different depths and locations.](image)

**FIGURE 3.** Soil temperatures at 5 and 10 cm depths from selected sites.

The presence of duff layers on untreated, logged surfaces strongly affects soil temperatures. The duff has a low thermal conductivity, consequently heat penetration is restricted. Removal of duff layers (scalping) can significantly increase mineral soil temperatures. For example, McMinn (1983) found scalping and mounding increased soil temperature at 6 cm by 6 and 9°C, respectively, over untreated soil in the SBSj1.
The depth and duration of snow affect soil temperature. Because snow, like duff, has a low thermal conductivity, it has the effect of insulating underlying soil from intense cold. The deeper the snow, the greater the insulating effect. For example, in Wisconsin, frost penetration was usually greater on south-facing slopes than on north-facing ones, presumably because snow cover was shallower (Sartz 1973). On the other hand, late-lying snow on north aspects obviously shortens the growing season and delays soil warming.

Shading is another factor affecting the energy balance at the soil surface. Shading by vegetation reduces the incident solar radiation, which is the driving force in soil temperature regimes. This is compensated to a minor degree by interception of long-wave radiation loss, which together with reduced insolation, results in diminished diurnal fluctuation.

Moist soils are cold soils for several reasons. They require high energy inputs per unit temperature increase (i.e., they have high heat capacities), and they generally have thick duff layers and heavy vegetative covers shading the ground.

Steep, north-facing slopes also suffer cold soil problems. Spring warming is delayed both by late-lying snow and reduced insolation.

2.3.2 Soil moisture

Although not generally considered a major ecological problem in regeneration in the northern interior (Appendix 4), soil moisture deficit can lead to mortality or stunted growth. For example, Burdett et al. (1984) have hypothesized that planting check in barefoot seedlings is partly a result of restricted uptake of water during the 1st year after outplanting. They observed that increasing moisture can improve growth during that critical period. Container stock is apparently less susceptible to drying out in the 1st year, though it may exhibit symptoms of planting check in the 2nd year (Burdett et al. 1984), probably because the resources of the plug material are exhausted.

The ability to regenerate fine roots rapidly in their new environment is a critical factor affecting outplant performance (Leaf et al. 1978). Immediately after outplanting, a young barefoot seedling must depend on its shocked, and frequently deformed, root system to deliver water to the shoot. Existing roots must extract water from a limited volume of soil and, during this critical time, soil moisture must not fall below a threshold value (Sutton 1978). Moisture contents at field capacity are optimum for root development and seedling survival, particularly for the first few weeks after outplanting. Dry weather conditions soon after planting can lead to high mortality. Thus, timing is critical, especially in summer planting.

During August, in drier biogeoclimatic units of the SBS and in much of the BWBS, soil moisture falls below field capacity in most well-drained soils. As a result, productivity probably drops off rapidly. Furthermore, soils on denuded sites that support a dense cover of herbaceous or grassy vegetation may have their moisture depleted by vigorous evapotranspiration. This may pose a significant competitive threat on some sites.

Soils in many ecosystems, such as the spruce-horsetail or black spruce-sphagnum units, have excessive soil moisture. Extensive forests on silty or clayey lacustrine soils in both zones have periodic excesses of soil water that significantly affect soil trafficability, as well as its regeneration and productivity.

2.3.3 Frost-heaving

Frost-heaving, a problem affecting planted seedlings throughout the SBS and BWBS zones, has frequently negated the otherwise beneficial effects of site preparation. It occurs when an ice lens forms beneath the surface of the soil, lifting the surface soil, litter, and outplanted seedlings. The effect is to break or disrupt root systems and expose them to desiccation. Plug stock is perceived to be more susceptible to frost-heaving than is barefoot (e.g., Lloyd 1982).
For frost-heaving to take place, several conditions must be met. Freezing and thawing cycles must induce soil ice formation and subsequently melt it so the cycle can begin again. As well, diurnal temperatures must rise above freezing during some part of the day and then dip below freezing.

The highest frequency of freeze-thaw cycles tends to be when mean monthly air temperatures are near zero. This corresponds to April, October, and November in most parts of the SBS, and to April and October in most parts of the southern BWBS. Since most of the SBS and BWBS is snow-covered in much of April and November, October is the month in which most frost-heaving takes place.

The presence of cluff tends to inhibit frost-heaving, because of its insulating properties. Frost-heaving is much more pronounced on exposed mineral soils.

In addition, a reserve of water must be available for frost-heaving to take place. It will not occur in dry soils.

Finally, the soil must have appropriate physical properties to allow water to move to the freezing surface. Soils with high unsaturated hydraulic conductivity (i.e., those offering relatively little resistance to unsaturated capillary flow) are most susceptible to frost-heaving. Medium-textured soils generally fall into this category. In coarse-textured soils, capillary flow is impeded because water films are distributed discontinuously in large pores. In fine-textured soils, the large particle surface area resists unsaturated capillary flow, and thus water transport is not fast enough to keep up with the freezing rate (Ballard 1981). However, capillary flow is not dependent only on texture. For example, compaction of coarse-textured soils (say, loamy sands) may increase hydraulic conductivity by making the soil pores more continuous, and thus may increase susceptibility to frost-heave.

Soil susceptibility to frost-heaving can be grouped into three classes (Soil Survey Staff, U.S. Department of Agriculture, 1971) as follows:

<table>
<thead>
<tr>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>sand</td>
<td>clay</td>
<td>silt</td>
</tr>
<tr>
<td>loamy sand</td>
<td>silty clay</td>
<td>silt loam</td>
</tr>
<tr>
<td>coarse sandy loam</td>
<td>sandy loam (medium)</td>
<td>silty clay loam</td>
</tr>
<tr>
<td></td>
<td>sandy clay loam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sandy clay</td>
<td>loam</td>
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<tr>
<td></td>
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<td>clay loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>very fine sandy loam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fine sandy loam</td>
</tr>
</tbody>
</table>
3 BACKLOG NSR IN THE SBS AND BWBS ZONES

3.1 Definition and Extent of NSR

Not Satisfactorily Restocked (NSR) land is defined as productive forest land that is supporting less than the minimum stocking level of silviculturally acceptable tree species, as defined by the regional stocking standards. Throughout the study area, that minimum stocking standard is 700 stems per hectare. If more than a set allowable time has elapsed since denudation, NSR land is considered "backlog." This time period, "the allowable regeneration delay," varies across the study area according to biogeoclimatic unit and ecosystem association. The delay may be short on brush-prone sites, where early establishment is critical; it may be longer for natural regeneration than for artificial regeneration. Forest land that is deemed NSR before the regeneration delay has elapsed is classified as "current" rather than "backlog."

Only healthy, well-spaced stems of preferred and acceptable species should contribute to stocking standards. How preferred and acceptable species are defined can greatly affect NSR statistics. The preferred and acceptable species in the study area include spruce (white and hybrid), lodgepole pine, and interior Douglas-fir. Some sites, however, also contain subalpine fir and occasionally black spruce. If this is included in the stocking rate calculation, it could greatly bias NSR statistics, particularly in areas where the species makes up a large part of the natural regeneration. (The fastest way to reduce NSR backlog estimates would be to include subalpine fir as an acceptable species.) Similarly, the proposed upgrading of aspen to a silviculturally acceptable species in the BWBS of the Prince George Forest Region would notably alter NSR statistics.

According to regional stocking standards, subalpine fir is unacceptable everywhere in the Prince George Forest Region. In the Prince Rupert Forest Region, it is acceptable in certain ecosystems within the SBS1 biogeoclimatic unit. In the Cariboo Forest Region, it is acceptable in mesic and wetter ecosystems in the SBSb and c subzones.

Statistics on NSR were obtained through Silviculture Branch's History Record System (HRS), from a report dated 31 October 1986. For the purpose of this report, NSR in openings greater than 5 years of age were classed as backlog, and NSR in openings less than 5 years old were classed as current. This definition corresponds closely to FRDA standards for interior allowable regeneration delay, although it does not separate out high brush sites, for which the delay is only 2 years. Since brush-prone sites are believed to carry a disproportionate amount of NSR land, these results overestimate current NSR and underestimate backlog land.

The HRS data indicate that just under 500,000 ha are classified as NSR land. About 70% of that total, or 345,166 ha, is located in the SBS zone. By region, the majority of NSR land in the study area falls within the Prince George Forest Region, totalling 381,616 ha or 78% of the total NSR in the area. The BWBS zone accounts for 144,088 ha of NSR (for good and medium sites only), or 29% of the total, even though only 19% of the disturbed area was located in that zone.

Figure 4 shows the percentage of disturbed area classed as NSR. According to this, the BWBS zone accounts for a disproportionately large amount of NSR land. This is undoubtedly the result of the extensive area affected by wildfire in the past, associated with settlement, land clearing and early resource development. In terms of current NSR, the BWBS zone still has a higher amount than the SBS zone. This seems to reflect the difficulty of establishing plantations in the BWBS because of competition from aspen and reedgrass. The Cariboo Forest Region (Quesnel TSA) shows a remarkably low rate of current NSR, though the data probably underestimate the actual NSR rate by several times (O. Steen, pers. comm.).
FIGURE 4. Percentage of disturbed area classed as NSR.

Figure 5 shows the NSR rate within the SBS and BWBS zones, compared with other biogeoclimatic zones in the area. Both the BWBS and the ESSF zones stand out as having significantly higher rates of NSR than other zones. The high rate for the BWBS is influenced by wildfire. In the Prince George Forest Region, both the BWBS and the ESSF have high rates of NSR, which is, to some extent, an index of the poor regeneration success rate.
3.2 Classification of Backlog Types

An aim of this project was to construct a classification of backlog types that are prevalent in the northern Interior. Variability both between and within biogecoclimatic units of the SBS and BWBS zones made this a difficult task. The types of vegetation confronting the rehabilitation forester do not always conform to the Biogeoclimatic Ecosystem Classification (BEC). A prime example is aspen, perhaps the single most important
backlog brush species in the region. It occurs throughout the SBS and BWBS zones, and across the hygrotope and trophotrope ranges. This wide ecological occurrence complicates its definition in ecosystem terms. Overstocked pine, resulting from recent wildfires, similarly ranges broadly over several biogeoclimatic units and ecosystems.

Rehabilitation deals primarily with seral vegetation. Since the BEC is based on climax or maturing seral forest ecosystems, it is not inherently suitable for backlog classification. Attempts are under way to develop a classification of seral vegetation within the BEC,\(^1\) but it is too soon to apply this work across the study region.

The backlog classification proposed here does not supersede the established ecosystem classification used by the B. C. Ministry of Forests and Lands. It merely forms a framework for describing existing rehabilitation practices. Backlog types are relevant largely in the brush clearance stage of backlog rehabilitation; once a site is cleared, the existing ecosystem classification is required for further (microsite preparation) treatment prescriptions (Figure 6).

\[\text{FIGURE 6. Conceptual basis of backlog classification.}\]

This report does not examine successional pathways associated with specific sites and site treatments. Current attempts to predict seral vegetation may yield great benefits in vegetation management and site treatment planning (C. DeLong, pers. comm.). Only a general discussion of the types of backlog vegetation is presented here.

3.3 Classification of Disturbance Types

The composition of vegetation on backlog sites depends in part on the way in which it was created. A classification based on cause of disturbance is one possible way of approaching the problem. Three broad groups of disturbance can be recognized:

1. wildfire
2. logging
3. other

These are discussed and subdivided into more detailed "classes" and "types" below. Backlog types describe the vegetation structure that is likely to be encountered. Figure 7 summarizes this interim classification.

FIGURE 7. Classification of backlog vegetation by disturbance types.
3.3.1 Wildfire

Wildfire is an important ecological determinant of forest structure throughout the study region, particularly in the BWBS zone and western parts of the SBS zone (Groups 1, 3 and 4). It is largely responsible for the mosaic of deciduous and coniferous cover that is characteristic of these northern forests. The extent of pure aspen or aspen-dominated stands is a testimony to widespread wildfire. Most older lodgepole pine forests probably owe their existence to wildfire. Its incidence is thought to have reached a maximum during the hundred years up to the middle of this century, when settlement, railroad construction, and early resource development triggered numerous anthropogenic wildfires (see Pojar et al. 1984). Since then, protection measures and increased concern for the economic consequences of accidental fire have diminished its extent - although accidents, lightning, and, to a lesser extent, escaped slashburns, still contribute to a continued incidence of wildfire.

Ecologically, backlog created by wildfire may not differ significantly from that created by logging followed by slashburning. The main differences between the two - for rehabilitation - are the presence of snags (after wildfire), the size and shape of the opening, the ground impact (which may be greater after wildfire than after a prescribed burn), and the amount and distribution of fuels. Consequently, in this classification both recent wildfire and logging overlap in the creation of early seral stage backlog types, namely the “herb complex” and “shrub complexes” (Fig. 7).

3.3.1.1 Recent wildfires

Recent wildfires are those in which herb or shrub complexes are present; that is, the backlog vegetation is less than about 5 m in height. Depending on the productivity of the site, the corresponding age of the vegetation may vary between 5 and 20 years. Major wildfires such as the Paul and Swiss in the SBSd subzone, the Straw in the SBSj1 unit, and the Osborne wildfire in the BWBS zone are current targets for rehabilitation.

When wildfire rages through a mature stand of timber, a sea of snags may remain. Salvage logging is only an option for approximately 2 years, after which the onset of “check” renders the timber unmerchantable. If left standing, snags complicate the rehabilitation of the site, in particular, interfering with aerial herbicide application.

3.3.1.2 Old wildfires

Old wildfires are associated with vegetation at later seral stages, including pure aspen and mixed deciduous stands. These have been created by wildfires that burned more than 10 or 15 years ago. By definition, the average height of the deciduous trees is greater than 5 m.

Although canopies are well established and more or less continuous, an understory of brush, grass (in the BWBS), and/or coniferous species (namely interior spruce or subalpine fir) is usually present. If spruce is a part of the understory community, the definition of NSR requires that it be present at unacceptable stocking rates (i.e., less than 700 stems per hectare). Rehabilitation of old wildfire sites in some areas is considered to be “hardwood conversion”. However, stands over about 40 years of age are generally low priorities for rehabilitation (M. Bruhm, pers. comm.).

Overstocked or stagnant pine is another backlog type that can develop following old wildfire.
3.3.2 Logging

Most NSR backlog in the northern Interior is the result of logging. Two major subclasses can be identified:

1. old Intermediate Utilization (I.U.) logging, including strip and diameter logging; and
2. clearcuts, both recent and old.

3.3.2.1 Strip logging

Intermediate Utilization logging was prevalent during the 1960’s and early 1970’s throughout the study area, consisting of either strip or diameter logging. Strip logging involved cutting all trees in a strip about 50-100 m wide and selectively cutting in leave-strips about the same width. (In many areas these cut- and leave-strips exhibit a herring-bone pattern.) Logging practices varied widely over the region. The objective was usually to facilitate natural regeneration of spruce, which would theoretically seed into the harvested strips from adjacent seed trees, thus forming the new crop.

Unfortunately, the system mostly failed to produce adequate restocking, and the harvested strips brushed in. Failure to restock may also have been due to lack of site preparation or poor timing of treatment in relation to seed availability (R. McMinn, pers. comm.). Since most strip-logged I.U. stands are about 15-30 years old, they do not comprise a range of seral stages as does the wildfire disturbance class. The most common backlog types are deciduous/conifer complexes, which pose a unique rehabilitation situation. Since the leave strips may contain merchantable timber, there may be an option to allow logging, which can precede or accompany rehabilitation of the brushed-in cut-strips.

3.3.2.2 Diameter logging

Diameter logging was common in old stands containing uneven-aged spruce. It commonly left inferior or damaged stems of spruce, and subalpine fir which was generally undesirable.

The vegetation that follows diameter logging is a mosaic of coniferous (particularly subalpine fir) and deciduous trees. The backlog type can be described as deciduous/conifer, in a pattern that is peculiar to diameter-logged stands. Options for rehabilitation may be more limited than for strip logging, since the remaining subalpine fir may be less commercially attractive. On the other hand, falling in preparation for a broadcast burn may be accomplished.

3.3.2.3 Clearcut logging

Clearcut logging had become the normal practice by the 1970’s. Throughout that decade, many clearcuts were left to regenerate naturally, even though treatments needed to promote natural regeneration were frequently not applied (R. McMinn, pers. comm.). Plantation failure was prevalent, and many of these failed clearcuts now constitute backlog NSR. Although site preparation and/or planting have become the norm in the recent 6 or 7 years, plantation failure is still too frequent, especially on brush-prone sites.

Backlog clearcuts are classified according to seral stage in the same fashion as wildfires. Recent clearcut failures are characterized by vegetation in an early seral stage, namely herbaceous and shrubby (up to 5 m in height) complexes. Old clearcut failures (normally dating from the late 1960’s) support intermediate seral stages, namely immature mixed deciduous, pure aspen, or deciduous/conifer forest with closed canopy. Clearcut failures, unlike wildfires, do not contain abundant snags to complicate rehabilitation, and closed-canopy brush commonly has a poorly developed understory. Both recent and old clearcut failures contain, in most cases, some stocking
of a silviculturally acceptable species, consisting of those individuals, planted or natural, which have survived despite vigorous competition. By definition, stocking ranges from just under 700 to 0 stems per hectare.

3.3.4 Other disturbances

The “other disturbance” class includes windthrow, insect, and pathological causes of backlog NSR. In the study region, these are a relatively insignificant cause of backlog land.

3.3.4.1 Windthrow

Rehabilitation of areas affected by windthrow usually involves salvage logging followed by broadcast burning or mechanical treatments. It is distinguished from other types of rehabilitation by the danger involved in bucking stressed stems, and by the limitations to machine maneuverability imposed by uprooted stumps.

3.3.4.2 Insect damage

Backlog due to insect damage is minor. It includes some stands damaged by spruce beetle (*Dendroctonus rufipennis*) which is mainly active in the Bowron Valley east of Prince George. Most accessible beetle-killed stands are salvage-logged, in which case sites should be considered under the logging disturbance class. Mountain pine beetle (*Dendroctonus ponderosae*) has infested enormous areas of lodgepole pine in the province - more than wildfire in 1985 - including 11 000 ha in the Prince Rupert Forest Region and about 1000 ha in the Prince George Forest Region as of 1985 (Wood and Van Sickle 1986). However, since a small proportion of infected stands is actually killed, pine beetle does not contribute greatly to regional NSR figures. Beetle-infested stands affect rehabilitation of adjacent NSR blocks because they constitute a greater fire hazard, thus reducing the attractiveness of prescribed fire as a treatment.

3.3.4.3 Pathological agents

Mortality of stands due to pathological agents is limited, except possibly in the case of mistletoe-infested pine stands. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) is present throughout the study area, but is not considered either a threat or a contributor to NSR backlog there. However, rehabilitation of mistletoe-infected pine is an on-going concern in adjacent parts of the Cariboo Forest Region.

3.4 Vegetation Types

Figure 8 shows the relationship between the backlog and the ecosystem classifications. Vegetation types need to be subdivided and sorted according to existing ecosystem units. Each vegetation type will occur in a wide range of ecosystems. The herb complex, for example, will be present following disturbance on most ecosystem units in the study area, although its composition will not be the same in all units. Because successional development depends on disturbance as well as on site characteristics, specific correlations between backlog vegetation types and ecosystem units have not been undertaken.
FIGURE 8. Relationship between backlog and ecosystem classification. Shaded areas delimit ecosystem groupings.

3.4.1 Herb complex

Definition

This complex is defined as being less than about 2 m high. It can develop following wildfire (in which case snags are usually present) or recent logging. The species making up this complex develop from seed or from surviving root systems, and colonize a site within 1 or 2 years of disturbance.

Nature and development

Some species are prolific seeders, colonizing denuded sites quickly. Fireweed is probably the best example of this type of specialist plant, and indeed, forms a major competitor in plantations established in very recent burns (although it also reproduces from rhizomes). Asteraceous species such as hawkweed (*Hieracium* spp.), thistle (*Cirsium canadensis*), and pearly everlasting (*Anaphalis margaritacea*) are other examples.
The seed from which competing vegetation develops may arrive on the site following disturbance (transported by wind or animals), or before. In the latter case, the nature of the seedbank, stored in the duff layer before logging, may determine the course of succession following disturbance. Many berry-producing species whose seed is disseminated by animals may also colonize disturbed areas through seed-banking. Examples include thimbleberry (*Rubus parviflorus*), red raspberry (*R. idaeus*), black twinberry (*Lonicera involucrata*), and elderberry (*Sambucus racemosa*) (Coates and Haeussler 1986a).

Other species produce seed that are not viable over long periods of time, and can therefore only invade by seeding-in after a site is disturbed. Willows (*Salix* spp.), sitka alder (*Alnus viridis* ssp. *sinuata*), and birch (*Betula papyrifera*) are examples of these species.

Many species can also reproduce by vegetative means, such as sprouting. If regenerative parts (e.g., roots, rhizomes, and stumps) survive disturbance, sprouting may occur. Vegetative reproduction can be highly significant because species exhibit faster height growth if they sprout from a pre-existing root system than if they grow from seed.

Species composition and rate of colonization depend strongly on the type of disturbance and degree of mineral soil exposure. For example, light treatments such as light burns or winter windrowing may leave root systems intact, thus favoring sprouting species such as raspberry and thimbleberry if they were present in the pre-disturbance stand. Alternatively, drastic treatments or intense wildfires that expose much mineral soil will promote establishment of birch, alder, willow, or cottonwood, depending on seed supply.

Most species in the herb complex are herbaceous, but significant amounts of shrubs, ferns, and grasses may also be present. Species composition varies widely across the study region.

**Subhygic to subhydric sites**

In subhygic to hygic ecosystems, which correspond to early seral stages of “devil’s club” and “horsetail” associations of the SBS described in Coates and Haeussler (1984), the herb complex consists of a distinctive array of species.

On wetter sites that have been burned (either by wildfire or prescribed fire) the complex commonly contains a higher proportion of shrubs than it does on drier sites. The reason is that pre-existing underground root systems can survive even a hot fire in the thick duff layers characteristic of these subhygic and hygic sites.

Plantation failure is disproportionately high on these sites, mainly because vegetative competition is so strong (D. Presslee, pers. comm.). Common species include lady fern (*Athyrium felix-femina*), thimbleberry, black twinberry, elderberry, wood horsetail (*Equisetum sylvaticum*), Indian hellebore (*Veratrum viride*), and the ubiquitous fireweed.

Paper birch, cottonwood (*Populus balsamifera*), sitka or mountain alder (*Alnus viridis* ssp. *sinuata* and *A. incana* ssp. *tenuifolia*, respectively), and various species of willow may occupy the site soon after denudation. These soon exceed the 2-m limit for this vegetation type, in which case it becomes a shrub complex.

Eis (1981) found that vegetative competition was severe on an alluvial site (probably ecosystem unit SBS2e/09.1, Spruce - Horsetail - Red-osier dogwood), because competing species were present under the discontinuous canopy before logging. Following canopy removal, these species (mainly black twinberry and mountain alder) were able to reproduce from established root systems. Consequently, brush competition was so intense that the annual height growth of planted spruce was less than 2 cm and suffered high mortality.
On a “devil’s club” site (probably ecosystem unit SBS2/08: Devil’s club - Lady fern), Eis (1981) reported that competing vegetation was slower to establish following clearcut logging, because species had to establish from seed. He also found grass species (*Calamagrostis* spp., *Cimnium latifolia*) to be common after logging in this ecosystem. Nevertheless, brush competition can be high within 2 years on these ecosystems (DeLong et al. 1986).

**Mesic to subxeric sites**

On drier sites, including those on mesic to subxeric moisture regimes in most biogeoclimatic units, the major species throughout the region are fireweed, thimbleberry, and red raspberry. Following disturbance these species, particularly fireweed, can achieve densities and vigor that can threaten growing seedlings (see Case Study 4 in Appendix 1). Dense fireweed, in addition to competing for light, nutrients, and moisture, can kill conifer seedlings by snowpress in the fall and winter. It can also produce a mat which prevents soil warming in the spring. Fireweed is a threat when it attains very high cover values and heights of 1 m or more (for example, on untreated strips in Case Study 3 in Appendix 1). On some burned sites, thimbleberry, red raspberry, and trailing black currant (*Ribes laxiflorum*) may co-dominate with fireweed.

**Reedgrass in the BWBS**

Following disturbance in the BWBS, the grasses (primarily *Calamagrostis scribneri*) frequently invade and establish at high densities. This grass is present in varying quantities in the undisturbed forest as an understory species. Following canopy removal, either by fire or by logging, surviving reedgrass may be stimulated to prolific seed production and rhizome extension. If a seed bed is available, which may normally be the case after an intense wildfire or logging operation, reedgrass will be the first to claim the site and can attain virtual dominance (see for example Case Study 12, Appendix 1). It is tolerant of a range of ecological conditions, and can be found growing vigorously on subxeric to subhygic ecosystems. It is a major competing species in the Fort St. John and Dawson Creek Forest Districts.

**3.4.2 Shrub complex**

**Definition**

This community represents a later successional stage than the herb community, from which it develops, and can develop following wildfire or logging. By definition, the shrub complex consists mainly of shrubby vegetation with an average height of between 2 and 5 m.

**Mesic to hygic sites**

In mesic to hygic ecosystems, this complex is dominated by mixtures of shrubs and saplings of deciduous tree species. Mountain alder may form dense thickets in wetter sites, especially where mineral soil has been exposed. Other common species include willow, aspen, birch, poplar, and Sitka alder. Also present in many sites are black gooseberry (*Ribes lacustre*), red-osier dogwood (*Cornus sericea*) and high-bush cranberry (*Viburnum edule*).

**Submesic to subxeric sites**

The shrub complex on dry sites usually contains mixtures of willow, birch, poplar, or Sitka alder. Interspersed throughout this complex may be young aspen clones. Cover is usually discontinuous on drier sites; brush tends to be clumped.
Since fire on drier sites is normally more intense than on wetter sites, sprouting may be reduced or even eliminated following severe fires. Shrub invasion is mostly through seeding, which is a much slower process. On wetter sites, vegetation will advance to the shrub stage in a matter of 2-3 years, whereas on drier sites, it may require up to 10 years or more.

The main exception to this is aspen, if root systems of pre-existing individuals survive the conflagration. Where this happens, dense clones sprout (Fig. 9), commonly dominating the site completely (Case Study 1, Appendix 1).

![Aspen clones](image)

**FIGURE 9.** Aspen clones in the SBS2 (01). Rehabilitation treatments must now deal with a high density of fast-growing aspen whips.

### 3.4.3 Pure aspen

**Definition**

Deciduous cover that is greater than 5 m tall and consists of at least 80% aspen is, in this classification, pure aspen. It can be found on old wildfire sites or on older clearcuts which now are classed as backlog NSR. The former may contain snags, which affect rehabilitation options.
Extent and development

Pure aspen is extensive in the study region on subxeric to subhygic sites. Aspen is a prominent member of post-burn seral stages in all biogeoclimatic units, with the exception of the SBSf and the southern portion of the K3 (C. DeLong, pers. comm.). It seems to be somewhat more abundant on south-facing slopes and on fine-textured soils in the SBS of the Prince Rupert Forest Region (Pojar et al. 1984). Its ability to produce pure or nearly pure stands is due to its sprouting action, which forms dense colonies of genetically identical individuals within each clone. Densities of up to 20 000-30 000 stems per hectare have been reported (W. Thorp, pers. comm.).

A pure aspen stand can be expected to exceed a height of 5 m in 5-15 years. Within clones, other deciduous species - such as willow, birch, or poplar - tend to be sparse. Pure aspen stands may be extremely dense initially, but as they develop, natural self-thinning creates a fairly evenly spaced mature stand. Gaps in the canopy are, of course, common and allow vigorous growth of understory shrubs.

Aspen is a short-lived tree and should be considered mature at about 55-90 years, although it can reportedly survive to the age of 200 (Haeussler and Coates 1986). At this stage, senescence may set in and aspen stands can begin to break apart. In the natural course of succession, spruce or subalpine fir form a suppressed - but continually growing - understory, which penetrates after 60-120 years, depending on the site conditions. Extensive areas of so-called pure aspen are partially stocked with understory spruce (Fig. 10). In such backlog stands, the advantages of clearing and starting from scratch must be weighed against the potential of the existing understory. As the conifers penetrate the aspen canopy, some whip damage may take place, but this does not appear to cause permanent damage (W. Thorp, pers. comm.).

Undergrowth in aspen stands (SBS)

Throughout most of the SBS zone, shrubs and herbs form the undergrowth, with patchy distribution corresponding to varying light levels beneath the canopy. Common species may include thimbleberry, black twinberry, grasses (e.g., Calamagrostis spp.), red-osier dogwood, prickly rose (Rosa acicularis), and high-bush cranberry. In natural gaps, red raspberry, fireweed, and willow may establish. Removing the overstory in rehabilitation sometimes stimulates the growth of these species, which then replace aspen as the main competitor for resources.

Undergrowth in aspen stands (BWBS)

In the BWBS zone, reedgrass is a common understory species in aspen forests. Due to its aggressive nature and ability to reproduce by both sexual and vegetative means, it is particularly difficult to control. The presence of reedgrass beneath an aspen canopy considerably complicates the rehabilitation of such stands.

3.4.4 Mixed deciduous

Definition

This backlog type consists of well-developed stands of deciduous trees at least 5 m tall, containing less than 80% aspen. Mixed deciduous stands may develop on old wildfire sites or on old logged openings. The former type may contain snags, especially if the wildfire took place less than 20 years ago and salvage logging was not complete.
FIGURE 10. Spruce understory in the Mackenzie District (SBSo). Young aspen canopy still allows sufficient light penetration for fairly good spruce growth. Aerial spraying would release this understory.

Extent and development

Mixed deciduous forest commonly contains substantial amounts of either aspen or cottonwood (balsam poplar east of the Rockies). Paper birch is another common associate. Estimates of brush problems in the Prince George Forest Region,\(^2\) for example, show that 85,220 ha on good and medium sites are dominated by cottonwood (including balsam poplar), with an additional 37,030 ha dominated by birch. These data include inventory classes “deciduous” and “deciduous/conifer,” and are taken from the Prince George Forest Region as a whole, thus including ESSF and ICH zones.

On subhygric or hygric sites, willow and mountain alder may also form a part of the canopy. If Sitka alder exceeds 5 m, a mixed deciduous stand can be formed. In the SBS zone, however, Sitka alder rarely attains this stature.

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This type differs from pure aspen mainly in that it is established partly from seed rather than from suckers. As a result, initial growth is not as rapid, and there is usually a delay in establishment following denudation (e.g., Case Study 3, Appendix 1). However, because these deciduous species can be prolific seeders, once they have established, high densities are possible. The relative proportion of the different species making up the type depends on the degree of mineral soil exposure and the presence of “seed trees” near the denuded site. Note that balsam poplar (Populus balsamifera ssp. balsamifera) may reproduce from both seed and sprouting (Coates and Haeussler 1986).

The main species constituting this type vary considerably in their growth and development. Cottonwood is generally faster growing than paper birch (Haeussler and Coates 1986), for example, and it is unlikely that the two species would be equally dominant on a site. Nearly pure cottonwood or balsam poplar stands do occur, mostly on alluvial sites, although birch may be present as scattered clumps or individuals. By definition, aspen may account for up to 80% of a mixed deciduous stand. Where it dominates, other deciduous species occupy gaps or other openings in the canopy. Under some conditions, such as following an intense wildfire, willow species may invade first and dominate the mixed deciduous complex. An example of this can be seen in parts of the Grove Fire near Prince George.

**Understory conifers**

Some mixed deciduous backlog types may contain a significant stocking of acceptable crop trees (400-700 stems per hectare) beneath the deciduous canopy. The presence of this understory clearly affects rehabilitation choices. If the understory spruce is well established, then rehabilitation is best directed at a conifer-release operation, rather than at a brush-clearing operation. In those biogeoclimatic units where subalpine fir is deemed to be an acceptable species, it should contribute to the stocking criterion given above.

### 3.4.5 Overstocked pine

This backlog type consists of pure lodgepole pine stands in which estimated “initial” density is greater than about 10,000 stems per hectare. Overstocked pine generally results from wildfire, but may also develop after logging, especially in parts of the SBSa subzone in the Cariboo Forest Region (O. Steen, pers. comm.).

If the overstocked stand is less than about 15 years old, and if the height of the dominant trees is less than about 2 m, then juvenile spacing remains a potential alternative to rehabilitation.

### 3.4.6 Stagnant pine

After the age of about 15 years, or a height of about 2 m, spacing becomes silviculturally inappropriate. Therefore, this backlog type does not carry a spacing option, and rehabilitation by knockdown or burning is a realistic option for bringing that forest land back into production.

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3.4.7 Deciduous/conifer

Definition

This type is an admixture of deciduous and coniferous trees, both of which are present in the canopy. It can follow old wildfires or I.U. logging.

Old wildfires

Deciduous/conifer vegetation types following old wildfires consist of suppressed spruce or subalpine fir in the process of emerging through the deciduous canopy. The age at which this takes place depends on many factors. Given the relatively slow growth of spruce under aspen (Steneker 1967), at least 60-80 years would elapse before suppressed understory conifers could penetrate a deciduous canopy.

Diameter logging

This backlog type is associated with a specific type of I.U. logging. It has a higher stocking rate with respect to conifers than other backlog types, but it is concentrated in subalpine fir (much of which may have been injured during logging) and immature (possibly inferior) spruce. The deciduous vegetation in this type is generally between 15 and 30 years old, and therefore has developed into tree form.

Strip logging

This type differs from other I.U.-logged stands in that partly stocked and clearcut strips of lands are arranged parallel to each other. Rehabilitation of this type is distinguished by the need to concentrate activities in the unstocked portion of these sites. The presence of partially stocked strips affects rehabilitation options: if prescribed fire is the preferred choice, then the stocked strips need to be felled, either for merchantable timber or for fuel distribution to prepare for a burn. The nature of the brush within the unstocked portion is highly variable, depending on the same factors listed under diameter-logged stands. Aspen, birch, cottonwood, or balsam poplar are probably the most common deciduous species within this type.
4 BRUSH CLEARANCE

4.1 Introduction

Rehabilitation of backlog lands involves the clearing or setting back of existing vegetation, normally followed by treatments designed to prepare planting microsites. It includes a wide array of methods, which can be applied to an assortment of backlog types. This section reports on existing brush-clearing methods and, where evidence exists, their relative success or failure. Many of these methods have only recently been introduced and are continually changing, making assessment of treatment effectiveness difficult.

Five groupings of backlog vegetation types can be associated with five rehabilitation types in the northern Interior:

1. hardwood conversion (pure aspen, mixed deciduous);
2. wildfires (herb and shrub complexes and deciduous/conifer, usually with snags);
3. overstocked pine (overstocked and stagnant pine);
4. recently failed openings (herb and shrub complexes); and
5. old logged openings (deciduous/conifer).

Brush clearance techniques include mechanical knockdown, manual clearing, chemical treatments, prescribed fire, or V-plows.

4.2 Hardwood Conversion (pure aspen and mixed deciduous)

Hardwood stand conversion is a rehabilitation objective throughout the study area, but nowhere is it as extensive as in the BWBS zone. It has been estimated that about 414 000 ha in the Peace TSA and a further 525 000 ha in the Fort Nelson TSA are dominated by aspen (Boateng 1984). However, since the recent introduction of a mill using aspen in Dawson Creek, the status of hardwood conversion in the BWBS as a rehabilitation objective has changed substantially. The rehabilitation of mixed deciduous stands has now become a more important focus in silvicultural plans.

Problems with conversion are confounded by an equally serious problem of competition from reedgrass, which is present in most, if not all, aspen stands. When an aspen overstory is removed, reedgrass beneath is stimulated by higher light and temperature levels, and a new problem replaces the old one.

Hardwood stand conversion in the SBS has focussed largely on aspen and mixed deciduous stands of a relatively immature stage, mostly less than about 40 years old. Many of the hardwood stands in the Prince George SBS contain understory spruce which would probably release if the hardwood canopy were removed. Over much of the SBS, the normal course of succession consists of early establishment of aspen or other hardwood, with spruce and perhaps subalpine fir eventually gaining dominance (eg: Draper and Hamilton 1984).

4.2.1 Machine clearing

In the BWBS, winter shearing, then piling or windrowing is the customary procedure for clearing a site.

In his experimental trials at Stewart Lake, west of Dawson Creek, L. Herring has demonstrated the increase in brush competition following winter clearing, unlike that after fall clearing. Superior brush control associated with fall treatment is attributed to underground suckers in aspen being cut during the
operation of the brush blade. However, even where the brush blade made a drastic impact, freedom from competing vegetation is short-lived. Where reedgrass is a component of the stand, knockdown and brushblading, if not thorough, can lead to increased competition. Case Study 12 (Appendix 1) is a rehabilitation site that was windrowed in winter, which did not achieve effective brush control.

Shearing is carried out with a shearing blade mounted on a powerful crawler tractor, commonly of D-8 size. The technique is believed to be most effective in winter, when the ground is frozen and stems are brittle. At this time, most stems of snags and deciduous trees are snapped off near the base. Larger trees are more likely to be uprooted when clearing is carried out in the fall. Winter shearing tends not to uproot trees. Residual stubs, if not killed, may sprout vigorously, thereby aggravating a brush problem. Several respondents indicated that herbicide applications are necessary following winter knockdown. Fall clearing is a more drastic treatment, which does provide some brush control, if only for one season (W. Thorp, pers. comm.).

In the Mackenzie Forest District, B.C. Forest Products has used a Rhoem side-cutter blade mounted on a D-8 crawler to treat mature aspen with stem diameters up to 50 cm and densities up to 250 stems per hectare (J. Zak 1986).

Windrowing or bunch-piling

Conventional windrowing, or bunch-piling, usually follows or takes place concurrently with shearing. A brush blade is used, which may or may not result in mineral soil exposure and a degree of brush control. Winter operations, while effective for shearing, do not allow much mineral soil exposure and tend not to disturb the surface organic material. Windrowing is discussed more fully in Section 5.3.2.4.

Marden duplex drum chopper

The Marden duplex drum chopper has been used on occasion, but few silviculturists in the area had much experience with it. West of the Rockies, the Marden has been used mostly for pine rehabilitation (Section 4.4). At Stewart Lake in the BWBS, it was found to be less effective than conventional clearing techniques (W. Thorp, pers. comm.). The Marden is best only when temperatures are below about -10°C, the ground is frozen, and the snow is not deep. If these conditions are not met, aspen tends to spring up behind the drums.

4.2.2 Chemical treatment

Aerial spraying

Although an effective means of killing hardwood overstories, aerial spraying is restricted by perceptions of complications in the permit application system and lack of experience, according to questionnaire response. The lead time necessary for permit approval is generally about 6-8 weeks, but can be longer in complex cases, especially if the approval is appealed. Some permit applications fail to gain approval because of conflicts with Fish and Wildlife Branch objectives.

Aerial applications of glyphosate have been shown to be effective against overstory aspen and balsam poplar at Stewart Lake (L. Herring, pers. comm.). In one trial, glyphosate was applied at the rate of 2.8 kg a.i./ha, from a boom spray system mounted on a helicopter. (Note that this is greater than the operational maximum rate of 2.1 kg a.i./ha.) Overstory trees were defoliated and suckering was minimal. However, understory aspen, poplar, and willow were less effectively treated and produced suckering in subsequent years. Worse, reedgrass was not controlled and dominated the site soon after treatment.
Aerial herbicide treatments have had mixed success in hardwood conversion because of their failure to control understory vegetation (W. Thorp, pers. comm.). The use of finer droplets may allow greater penetration through the hardwood canopy, thereby controlling understory competitors (J. Boateng, pers. comm.). Use of finer droplets, however, must be weighed against the greater potential for drift.

The main environmental constraint is proximity to watercourses, about which a 10-m pesticide-free zone (PFZ) must be maintained. For aerial application, a considerable drift buffer zone must also be planned, so aerial spraying normally does not take place within about 100 m of a watercourse or standing body of water. In the Prince Rupert Forest Region, spraying can approach 30 m of a watercourse, if a card line is laid and windspeed and direction are favorable (F. Newhouse, pers. comm.). Since a disproportionate number of backlog sites are located in subhygic to hygic ecosystems which are associated with standing or running water, environmental constraints can impose major limitations to the use of herbicides. However, these constraints also apply to mechanical brush clearance.

The aerial application of hexazinone “gridballs” has also been tried at Stewart Lake, with impressive results: the balls, applied from a helicopter at the rate of 4.0 kg a.i./ha, penetrated through the aspen canopy to the ground, and were effective against reedgrass, willow, and aspen. Gridballs were not registered for general forestry use, but were used only under special research permit. It is anticipated that another pelletized form of hexazinone (pronone) will be registered for forestry use in the future (e.g., Sutton 1986). Herbicide screening trials for reedgrass and aspen are currently being carried out by L. Herring under FRDA Project 1.3.

**Timing**

Silviculturists do not agree on the optimum time of treatment. Most aerial applications take place between mid-July and early September. In Ontario, Sutton (1984a), using a mist-blower on young aspen sprouts, found summer applications of both glyphosate and hexazinone to be more effective against aspen than fall applications. Exposure of actively growing conifers to glyphosate may result in damage, although the extent and degree appear to be variable (Sutton 1984a). Early fall applications are also believed to be effective (B.C. MOFL 1987). Rain, falling within 6-12 hours after spraying, will limit the effectiveness of aerially applied glyphosate. On the other hand, if target trees are experiencing moisture stress, mortality and control of root suckering may be restricted. Glyphosate is used far more than 2,4-D, despite its greater cost, because of perceived superiority in effectiveness, especially in controlling aspen suckering (F. Gunderson, pers. comm.). Application rates for hardwood conversion are normally set near the maximum operational rate suggested by the manufacturer, namely about 2.1 kg a.i./ha (6 L/ha).

**Planting**

Prompt planting following aerial spraying of immature deciduous canopies has been reported as being successful in the Mackenzie Forest District (D. Greenley, pers. comm.). If understory control has not been effected, a second herbicide application will be necessary. Planting beneath mature hardwoods that have been chemically treated may not be feasible because of the potential hazard of falling stems and branches.

**Ground injection**

Ground injection of the soil-active herbicide hexazinone has been used sparingly as a rehabilitation measure. It received temporary registration in Canada only in 1984. Depending on the nature of vegetation, it has been applied on a grid pattern, with spot applications usually spaced at 1.5- to 4-m intervals. It can also be applied selectively at the base of competing trees or shrubs. Hexazinone application has best results during cool, wet days, during which percolating rainwater will transmit the
chemical into the soil. Once in the soil, conditions must be such that hexazinone can translocate into the roots. Since it may damage crop trees, it cannot be applied close to them. The manufacturer has recommended that injections or ground-spraying be more than 1 m from a crop tree stem.

Spot gun

Hexazinone is normally applied using a spot gun, with which a specified dosage is squirted onto the surface of duff or exposed mineral soil. The efficacy of this treatment seems to diminish with increasing duff thickness. In the Prince Rupert Forest Region, it has been recommended that sites containing duff thicker than 15 cm be screeded before spot gun application; otherwise, a “spear” should be used (Geissler and Newhouse 1987). In the Mackenzie Forest District, a “screw and squirt” technique is used to apply hexazinone in areas of thick duff (J. Zak, pers. comm.). Caulk boots are used to make the screw.

Spear

The spear consists of a sharp cone-shaped nozzle at the end of a metre-long tube, through which hexazinone can be applied. The spear can penetrate the duff layer and deliver the herbicide directly to the mineral soil surface. Herbs and shrubs which confine their rooting to the duff layer may not be affected by ground-injected hexazinone (Geissler and Newhouse 1987).

Movement of hexazinone

Once it has reached the mineral soil, hexazinone is relatively mobile and has the potential, under certain conditions, to move out of the treatment area. In the Prince Rupert Forest Region, it has been observed in a few instances to move more than 50 m (Geissler and Newhouse 1987). Conditions favoring overland flow, such as compacted skidtrails, frozen soil, ditches or natural channels, may promote off-site movement. In medium textured soils, such as silty loams, hexazinone leaching may be too slow to threaten groundwater quality (Feng 1987). In contrast, sites with a high water table or coarse textured soils with a potential for saturation may be poor candidates for hexazinone application because of the risk of groundwater contamination.

Disadvantages

The major disadvantage to the use of herbicides to kill hardwood overstories is that the snags created become a serious hazard to silvicultural crews for many years, until they fall down naturally. Control of understory vegetation has also been a problem.

Stem injection

Stem injection treatments (such as “hack and squirt”) are used to rehabilitate aspen or mixed hardwood stands. They are also extensively used in conifer release and pre-harvest brushing, where deciduous trees are overtopping or co-dominating a spruce stand, respectively.

A primary objective of aspen rehabilitation is to prevent resprouting once the canopy is cleared. If stem injection of mature aspen precedes harvesting or mechanical clearing by a sufficient time period, the injected glyphosate will have time to translocate to the roots, thus inhibiting sprouting (F. Gunderson, pers. comm.). Although top-kill and leaf area reduction is soon apparent following injection, a lead time of at least 3 years is probably needed for effective root kill (B. Zak, pers. comm.).
Stem injection for site preparation and weed seed tree control is more intensively practiced in the SBS of the Prince George Forest Region than elsewhere in British Columbia. In 1986, nearly 6,900 ha were treated using stem injections of glyphosate (Humphries 1987). About 90% of this total was concentrated in the Mackenzie Forest District, reflecting an aggressive program undertaken by B.C. Forest Products.

Methods

Hack and squirt is the most common form of tree injection. It entails the cutting of a notch or frill with a downward stroke of an axe or hatchet, followed by a squirt of herbicide (usually glyphosate) into the notch. The dosage and number of notches per stem are regulated by stem diameter and the chemical used. Advantages of the hack and squirt technique include the simplicity (and thus reliability) of the equipment and its use. It can be used year round, if mixed with antifreeze during cold snaps (F. Gunderson, pers. comm.).

Other techniques include a "hypohatchet", in which the herbicide is delivered through a small tube into the cutting blade of the hatchet. The chemical is applied in a single motion. In some cases, the delivery channel may clog with wood splinters, and there is a potential for splashing if chemical remains on the blade from a previous cut (Bancroft 1987).

The "injection lance" has been developed by the Silviculture and Research Branches of the B.C. Ministry of Forests and Lands (Gilmour 1984). It consists of a 1.8 m lance with an injection head which releases herbicide when it is jabbed against a tree. Like the hypohatchet, the injection lance allows stem treatment in a single movement. However, its weight and cost are potential disadvantages (Henigman and Beardsley 1985). In the Mackenzie Forest District, B.C. Forest Products uses a punch and fill technique to inject glyphosate into residual hardwood stems. Fewer accidents have been reported using this injector method than with other methods employing a hatchet (J. Zak, pers. comm.).

The "Dillistone Weed-Do Injector" has been used on a trial basis in the northern interior. This implement injects a 0.22-inch cartridge filled with herbicide and a solidifying agent into the tree. The number of cartridges per tree (dosage) depends on the stem diameter and the chemical used. The advantages of this technique are that it can be used even in heavy rain, and it appears to be relatively safe with little chance of worker contact. On the other hand, the technique does not adequately mark treated stems, resulting in a high chance of missed or over-treated stems.

Cut-stump treatments

"Cut-stump" treatments are used in the rehabilitation of immature deciduous stands in which manual brushing would lead to excessive coppicing. Target species are commonly birch, alder and willow. The treatment involves severing a stem near to the ground with a brush or clearing saw, followed by prompt application of a measured dose of herbicide, usually applied with a spray bottle. Combined "brush saw herbicide applicators" are available, which sever the stem and apply a measured dose of herbicide in one operation. In the Mackenzie Forest District, this equipment has been used on aspen and other deciduous species with stem diameters between 5 and 15 cm (J. Zak, pers. comm.). In preliminary trials it has also been successful against Sitka alder in the Vanderhoof Forest District (SBSd) (B. Walker, pers. comm.).

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Disadvantages of the cut-stump technique include potential exposure of workers in their knee to ankle zone and, in the case of the brush saw/herbicide applicators, the difficulty of finding experienced and competent contractors (J. Henigman, pers. comm.).

Combination treatments

In addition to their use in hardwood conversion or brush clearing, chemical treatments have been tested as secondary treatments, either alone or in combination with second-pass mechanical treatments. Experimental plots at Stewart Lake indicate that pre-treatment with hexazinone provided effective control of reedgrass and hardwood suckering. Glyphosate was found to be less effective than hexazinone against reedgrass. The use of aerially applied glyphosate, in combination with mechanical treatments, is the subject of an ongoing research effort, part of which is being carried out at Stewart Lake (FRDA Projects 1.2 and 1.3, both led by L. Herring).

4.2.3 Prescribed fire

At Stewart Lake in the Dawson Creek Forest District, prescribed fire on untreated brush and on chemically treated brush has been tested. The site had been subjected to a number of wildfires in the past and, at the time of the trial, supported dense aspen and balsam poplar, as well as reedgrass. Part of the site was treated with 2.8 kg a.i./ha of glyphosate in June 1983. The following year in May, the site was broadcast-burned. The browned area received a higher ground impact, and poplar suckering was effectively controlled; reedgrass, however, recovered almost immediately and dominated the site. The part of the site not pretreated by glyphosate sustained a low ground impact, and poplar suckering was not controlled. Because of the tolerance of reedgrass (and, in the absence of glyphosate, poplar) to fire, it does not seem to be an effective rehabilitation treatment except as a clearing operation to facilitate secondary mechanical treatment (L. Herring, pers. comm.). Higher burn impacts may be more effective.

Operationally, there are two options for the use of prescribed fire in rehabilitation:

1. machine knockdown followed by broadcast burning, or
2. brown and burn.

If enough fuel is present on the block after knockdown is completed, a broadcast burn may be prescribed. Fuel loading depends on the composition and structure of the backlog stand. The decision of whether to broadcast burn or not depends also on the desired impact. If a secondary treatment is envisaged, then a high impact is not necessary, and it will suffice to prescribe a fire that will consume much of the fine fuel, but not the duff. On the other hand, if the broadcast burn constitutes the final treatment before planting, then burn impacts must be high enough to consume part of the duff layer and set back competing vegetation. High impact burns have been considered necessary in subhygric to hygric ecosystems in the past.

Distribution of fuel loadings are also a factor for consideration: many backlog stands exhibit a clumped pattern of hardwood trees and shrubs. This complex, after having been knocked down, may not provide a slash cover sufficiently continuous to carry a broadcast burn. The composition of a hardwood stand has a bearing on the efficacy of the burn. For example, birch is widely believed to have a lower moisture content than aspen or cottonwood, and therefore will be more effective in carrying a broadcast burn (T. Calhoun, pers. comm.). Alternatively, a birch stand may require a shorter drying period than a poplar stand, after knockdown.
Timing of prescribed fire

The timing of the fire may be set using the prescribed fire predictor (Muraro 1975), but burning knocked-down backlog hardwood stands is still outside of the experience of most silviculturists. Early summer knockdown, followed by fall broadcast burning, would be an ideal sequence if moisture levels of the fuel drop to an appropriate level. Deciduous slash is believed to be more difficult to burn than regular logging slash, because of the relative paucity of fine fuels (B. Hawkes, pers. comm.). A minimum of several months is probably necessary to allow sufficient drying. Throughout the wetter units of the SBS, the average number of ignition days is very low after the end of August, and the chance of having a successful burn consequently diminishes (Vihmanek and Feller 1985). Overwintering of the slash would tend to compress it and this, together with invading herbaceous and shrubby brush, may result in a less intense fire than desired. Backlog sites receiving lower impact fires will generally need to be treated again, either mechanically or chemically.

4.3 Wildfire Rehabilitation

In the BWBS, the Osborne Fire, located about 50 km northwest of Fort St. John, is an example of wildfire rehabilitation. Case Study 12 (Appendix 1) examines the status of seedling performance in one part of this fire.

Rehabilitation was initiated promptly on this site. During the winter after the fire, knockdown and windrowing cleared snags. In the spring, rows were burned. Bracke mounding was a secondary treatment on the cleared site. Spruce plugs were spring-planted in 1985.

Knockdown and clearing are usually more efficient and cleaner in the winter than in the summer or fall (as less soil is moved into the piles or rows), but because the roots of competing vegetation are left intact, the site is quickly dominated by reedgrass and aspen (see also FRDA Project 1.2). This usually necessitates chemical treatment, applied either before planting (hexazinone ground-injection) or after planting (glyphosate backpack or aerial spray). Despite summer or fall piling being more drastic and exposing mineral soil, immediate planting without further mechanical, chemical or combination treatments has little chance of success in the face of potentially severe competition from aspen and reedgrass.

Reedgrass is a major problem in wildfire rehabilitation in the BWBS zone. The Osborne Fire showed that this grass can attain consistently high covers with average heights over 50 cm in only 2 years. Such severe competition allows little respite for seedlings planted in small patches or ripper plow berm. Either more drastic treatments, which effectively set back competing vegetation from a larger area (such as moldboard plows or discs), or chemical treatments are required to give seedlings breathing room. Even moldboard plows and discs may not bury reedgrass sufficiently to prevent resprouting (W. Thorp, pers. comm.).

Examples of wildfire rehabilitation in the SBS zone include the Paul and Swiss fires in the Morice (Houston) District. The Paul Fire took place in 1961, destroying about 8000 ha of forest; the Swiss Fire took place in 1983, destroying 18 000 ha.

Snag falling

The presence of snags is the distinguishing characteristic of this disturbance type. These are removed as a first step in rehabilitation, either by cabling or blade knockdown. On recent fires, especially if they are reasonably accessible, snags are made available for salvage logging or firewood collection before rehabilitation commences.

Snag falling is frequently a prerequisite to secondary treatment and planting, especially in older fires. As snags are weakened by age, insects and rot, they become an increasing hazard to planters. In the Paul Fire, planting under snags was allowed in small areas where mechanical knockdown was precluded by the sites’ sensitivity to heavy traffic. Snags deemed hazardous (for example, those leaning or deeply burned) were felled by chain saw.
Snag falling is commonly accomplished by a bulldozer equipped with a piling blade, or by cabling with an anchor chain between two heavy crawlers.

Cabling

Cabling may be as cost effective as shearing with a blade. In the Paul Fire, cabling had the advantage of aligning slash, thereby facilitating windrowing. On the other hand, the difficulty of coordinating two machines was cited as a disadvantage (I. Lister, pers. comm.). According to some questionnaire respondents, cabling is falling out of favor because of expense, the high level of operator skill required, and the excessive damage to the ground. Effectiveness and soil disturbance are heavily dependent on operator skill and/or degree of supervision.

Powerful prime movers (D-8 or larger) are needed to knock down snags, especially on recent wildfire sites, since root systems are still intact and stems are not yet weakened by rot. Clean shearing of stems is preferred, to keep stumps (and soil) on the site and to allow a tighter windrow or pile.

Knockdown is then immediately followed by windrowing or piling. Burning of windrows or piles is subject to the policy of the district office.

Rehabilitation options

Once the slash has been piled and burned, two options may be followed. One is to plant immediately with large stock. This is the preferred option if brush hazard is not high, and ground disturbance has created planting spots. If the site is brush-prone, an aerial herbicide treatment is planned, with planting carried out as soon after as possible. A possible sequence in this case would be:

1. knockdown and windrow in winter;
2. burn the rows the following fall; and
3. aerial herbicide in June or early July, then plant with ‘hot.lifted‘ stock (F. Newhouse, pers. comm.).

Thus, the time elapsed between initiating rehabilitation and planting is about 18 months.

Rehabilitation plans are usually preceded by a careful stratification of the area to be treated. Inoperable areas are identified and marked for alternative treatment, either brown and burn, aerial herbicide alone, and/or fill-in planting, if partial stocking is present.

4.4 Overstocked Pine

Rehabilitation of wildfires which have naturally regenerated to overstocked stands of pine is a problem particularly in the SBS zone. In the Lakes Forest District, for example, there are an estimated 86 000 ha of overstocked pine, aged 40-60 years (Blackwell et al. 1986).

Wildfire in live lodgepole pine stands often kill the trees but not the seed within attached cones. The heat of the fire opens the resin bonds of the cones, allowing viable seed to escape. If sufficient mineral soil has been exposed by the fire, which is normally the case in these drier areas where duff layers are thin, a very high density (from 50 000 to 500 000 stems per hectare) of pine seedlings can become established. The result is an overstocked stand of young pine beneath standing snags.
Timing

Depending on the age, density and site quality, individual trees may experience repression from an early age. Volume and height increment can therefore be significantly different from the site potential. In general, it is believed that the older the stand, the greater the loss in volume - which cannot be regained. Furthermore, the ability of the trees to experience height growth release is diminished. Studies by Goudie indicate that release at age 18 or greater yielded an immediate response in diameter, but response in height increment was delayed significantly or was non-existent.\(^5\) Release at age 11, however, yielded a response in height growth. Overstocked pine stands therefore have to be treated early if a satisfactory volume is expected over a reasonable rotation period.

It is generally perceived that overstocked pine must be treated before 15 years has elapsed, although if a biologically relevant threshold age exists it is probably stand- and site-specific. Juvenile spacing comes under the category of "stand tending," rather than "rehabilitation," but different methods and their effectiveness need to be considered in deciding whether to rehabilitate by knockdown or burning, or to tend by spacing.

Spacing

Juvenile spacing is normally carried out manually with brush saws, shears or clippers. Shears and clippers are effective in high density stands in which stems are less than 5 cm diameter (B.C. MOFL 1984). Chain saws are considered unwieldy in dense stands, and therefore uneconomical. Conventional juvenile spacing of dense stands requires mechanical strip thinning as a prerequisite, to allow access into the stand. Falling of snags or residuals normally precedes spacing operations, primarily for safety reasons. Target spacing is set by the Regional Stand Tending Guidelines.

Strip spacing, using a fiailling device attached to a skidder, has been tested on one overstocked pine stand in the Vanderhoof Forest District. This technique cleared strips about 2.5 m wide, leaving approximately 3 m leave-strips. The intent was to release trees along the edges of the strips, and facilitate access for manual spacing of trees within the leave-strips. Unfortunately, either the spacing was left too late, or site quality was inadequate to allow a response, because no height response was observed (Fig. 11).

Many silviculturists in the SBS zone agree that spacing pine stands less than 12-15 years old is an economically viable alternative to rehabilitation, if funding and time are available. The choice of spacing or knockdown depends on biological and economic factors. The presence of a significant subalpine fir component in the stand (for example, in the SBS\(\text{Se2}\)) may tip the balance in favor of knockdown (J. Casteel, pers. comm.). Dense snags may render spacing too expensive, in addition to creating an excessive fire hazard once they have fallen.

In parts of the SBS\(\text{Se2}\), and certainly in the SBS\(\text{S1}\) and f subzones, spacing may lead to snow breakage. Spindly juvenile pine is especially vulnerable (B. Williams, pers. comm.). In the SBS\(\text{Sk2}\) and k3, and throughout the SBS\(\text{Sd}\), snow loadings are generally not heavy enough to cause significant damage (B. Walker, pers. comm.).

A number of interviewees stated that because funds for spacing programs are seriously limited, many pine stands are allowed to attain a stagnant condition, at which point there is no alternative to knockdown (J. Casteel, pers. comm.). On the other hand, spacing programs are often suitable projects for federal employment projects.

\(^5\) Goudie, 1980.
Shearing and windrowing

Probably the most common rehabilitative treatment is winter shearing followed by piling or windrowing. It is accomplished with a straight angling blade mounted on a powerful crawler, usually D-8 or D-9 size.

Shearing is most effective in winter when the ground is frozen and stems are brittle. When this operation is carried out under mild conditions, stems may flex beneath the blade as it passes, only to spring up afterwards. The remaining stubs pose a problem to subsequent treatment or planting. It has been reported that ambient temperatures lower than about -10°C are needed for effective shearing (D. van Dolah, pers. comm.). Piling is difficult when snow depths are greater than about 50 cm. Winter operations in the Vanderhoof Forest District, however, have the advantage that contractors who have the necessary heavy-duty equipment are available. These individuals are busy with agricultural land-clearing in non-winter months so that contract bids are competitive, with costs in the range of $250-300/ha (not including windrow burning) (D. van Dolah, pers. comm.).

Windrows are burned the following fall. Because brush competition is usually not severe in lodgepole pine sites, the site can be planted in the subsequent year. Frequently, rehabilitated blocks will contain portions of subhygric or hygric sites, including depressions, gullies or draws (Fig. 12). These areas can be planted to large stock spruce (for example PSB 415), but, without special treatment (such as mounding), survival is usually poor.
Prescribed burning

Prescribed broadcast burning following knockdown is another option. Knockdown and burn being investigated in FRDA Project 1.13 (Blackwell et al. 1986) has been found to be cheaper than knockdown and windrow, because of lower preparation and mop-up costs. Knockdown for the broadcast burn treatment was carried out in September 1985, with burning taking place the following spring and summer. Impact of the burns ranged from "low" (late May) to "high" (late July), corresponding to the curing of the slash and the prevailing weather conditions.

Goudie has suggested that, if feasible, burning a live pine stand at some point after it has developed a cone crop, but before an age of about 25 years, may be a viable option. Secondary stands developing from early burns are believed to be more widely spaced than the original. Although control may be an important consideration, the costs of this option could be well below that of mechanical knockdown.
Marden brush chopper

The Marden brush chopper has been used to rehabilitate stagnant pine. This equipment is restricted to smooth, level terrain, otherwise the drums will ride over obstructions such as rocks and stumps. Also, the implement is unwieldy, with high power requirements (Breadon 1987).

Resource conflicts

Land-use conflicts with Fish and Wildlife Branch may be encountered on pine rehabilitation sites. Overstocked pine stands are a natural part of the forest, and certain species, such as snowshoe hare, favor them for shelter and hiding cover. At the same time, hares may cause unacceptable levels of damage in young lodgepole pine stands, thus constituting a silvicultural problem in certain areas (Sullivan 1984).

4.5 Recently Failed Logged Openings (Herb and Shrub Complexes)

The rehabilitation of logged openings which have failed to restock within about 10 years is an important activity in both the Prince George (M. Bruhm, pers. comm.) and Prince Rupert (F. Newhouse, pers. comm.) forest regions. Clearing early seral vegetation of herbs and shrubs is the objective in this disturbance type, and thus a separate brush clearance operation is not always required. Common treatments involve the use of herbicide sprays, brown and burn, and V-plows. Machine clearing and piling may be used on older sites dominated by hardwoods, such as alder, aspen and cottonwood. Rehabilitation of sites carrying hardwood stands greater than 5 m tall is discussed under “hardwood conversion” (Section 4.2).

Sitka alder

Sitka alder is an important brush species on backlog sites in the SBS zones. It can occur as nearly pure stands, in the form of dense thickets, or interspersed with pine or spruce. Some silviculturists view low density alder as a favorable component within a growing plantation, as crop tree growth is believed to benefit from the additional nitrogen fixed by the elders’ root nodules (C. von Hahn, pers. comm.). This is corroborated on one site by Ballard (1984), who observed that leader length of spruce was 50% greater on scalped sites in which alder had invaded, than on sites which were alder free. However, when alder cover reaches a certain threshold cover, competition for light, nutrients and moisture probably begins to compensate for any benefit accrued.

4.5.1 Chemical treatments

The effectiveness of herbicides in controlling early seral vegetation is still inadequately studied. Trials conducted by L. Herring in the Bowron River valley east of Prince George (SBSf) suggest that the effectiveness of chemical applications may be short-lived, in part because affected weed species may quickly be replaced by others (C. DeLong, pers. comm.).

Aerial

In Case Study 13 (Appendix 1), an aerial application of glyphosate was used to clear brush on a failed plantation of spruce in the BWBSd2 unit in the Fort St. John District (Fig. 13). Spraying was applied in August 1985, with fill-in planting following in 1986. The spray was effective against reedgrass, aspen and several other species such as rose (*Rosa acicularis*) and fireweed, but only partly effective against Sitka alder. Surviving spruce seedlings were unaffected by the spray, but residual subalpine fir experienced leader die-back. The dead grass mat was more than 10 cm thick in places and required aggressive screeving while planting. Remote sites such as this may not be economically treated by specialized equipment in a second pass operation. One alternative now being tested in the Fort St. John Forest District is a hand-held power scalper (the “Hawk Power Scalper”), which may provide effective spot screeving.
FIGURE 13. Aerial spraying in the Fort St. John Forest District (BWBSd2). The spraying was very effective against reedgrass. Raw fill-in planting was prescribed, but requires rigorous screening of the dead grass mat (Case Study 13, Appendix 1).

Backlog sites occupied by Sitka alder ("shrub complex") can also be cleared with the use of chemicals. In the Vanderhoof Forest District, for example, 2,4-D, with diesel as a surfactant, was applied to alder brushfields (C. von Hahn, pers. comm.). This chemical is believed to be less effective than glyphosate against most species, but appears to be more effective against alder, willow and birch (Haeussler and Coates 1986). It is also cheaper.

Manual brushing of alder is seen as ineffective because of the rapid rate of coppicing from stem collars (B. Walker, pers. comm.). However, this can be eliminated by using a brush saw with a spray attachment, which adds herbicide onto the cut stem (cut-stump treatment, discussed under "Hardwood Conversion"). Operationally this has not been extensively tested in the northern Interior, but preliminary trials suggest that it is expensive and ineffective on small diameter stumps (J. Perry, pers. comm.), such as those which may be expected on recently failed logged openings. Stems less than about 5 cm in diameter tend to whip away from the saw (J. Zak, pers. comm.).

Aerial sprays are gaining acceptance because of their low per-hectare cost if applied on a large block. Many backlog sites in the northern Interior contain residual aspen or other deciduous trees which must be felled before aerial spraying, to ensure safe and homogeneous application (F. Gunderson, pers. comm.).
Backpack sprays are more costly than aerial applications, but are less controversial and more likely to be approved (F. Gunderson, pers. comm.). Furthermore, because drift-buffer zones are narrower, there is greater flexibility in the range of sites treated. Backpack spraying is ineffective or inefficient in brush more than about 2 m high. As well, there is a greater operator risk associated with backpack spraying than with aerial application.\(^8\) Protective equipment worn by the operators, required by the B.C. Workers Compensation Board, restricts movement and limits effectiveness in heavy brush.

**Rehabilitation options following herbicide use**

After herbicide application, a number of options are available. Raw-planting of large stock pine or spruce can be carried out directly. If hexazinone was used, however, a 1-year buffer period is recommended. The success of this operation depends on the condition of the ground surface. If a duff layer remains intact, or if a litter layer has built up, seedling performance may be poor, even if stock quality and vigor are high.

On the other hand, a secondary mechanical treatment can be implemented such as disc trenching or mounding. If mechanical treatment follows the application of glyphosate before the herbicide has time to translocate to the roots, resprouting may occur (J. Perry, pers. comm.). Consequently, an appropriate time delay should be established on a site-specific basis.

**4.5.2 Brown and burn**

This option has been explored in a problem analysis by Vilmanek and Feller (1985), and is generally perceived as being a potentially effective way of achieving site rehabilitation by non-mechanical means. It is seen as a realistic option on sites in which mechanical site preparation is not feasible because of slope restrictions or sensitivity to heavy traffic. However, fireguards built by heavy equipment will still be necessary. It is also an option where knocked down backlog vegetation would not carry a broadcast burn. Its advantages are most clearly seen in herbaceous and shrubby complexes where windrowing is not an option.

An important limitation to the brown and burn method is that opportunities for burning in the wetter portions of the SBS become very limited after late summer. Thus, browning would have to take place in early summer, with burning no more than 2 months later.

The success of a brown and burn operation also depends on the presence of fuel to sustain the fire (B. Hawkes, pers. comm.). On failed plantations, browning vegetation will complement existing logging slash as fuel. The original logging method and site preparation treatment is therefore important. Many logged sites were not site-prepared, and were either planted as is or left for natural regeneration. Logging slash was left on the ground and is available for burning. Unfortunately the fine fuel component, which helps to carry and spread the burn, will have decomposed. In this case, browning of existing brush is required.

Older blocks that have previously been broadcast burned contain insufficient coarse fuel to sustain a rehabilitating burn. Similarly, if the failed plantations have been windrowed or piled, then fuel loads may not be sufficient for a brown and burn treatment.

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\(^8\) Bancroft, 1987.
4.5.3 V-plows

V-plows have been used in the rehabilitation of recently logged backlog sites to clear brush and, at the same time, prepare planting spots. In the Prince George Forest Region, backlog rehabilitation plans are de-emphasizing V-plow treatments (M. Bruhm, pers. comm.) because of perceived site degradation, inconsistent creation of plantable microsites, and unsatisfactory seedling performance. (For discussion of microsite creation by V-plow, see Section 5.3.2.2.)

Suitability

V-plowing is perceived to be a realistic option in treating certain backlog sites dominated by herb and shrub complexes (B. Walker, pers. comm.). For example, V-plows have been used to clear trails and create planting spots on alder sites, provided the brush height is less than 4 or 5 m.

Generally, V-plowing is a questionable practice on fine textured soils (see Section 5.3.2.2). However, if a thick Ah horizon is present the treatment may produce satisfactory results. Such conditions are frequently associated with alder sites.

The treatment is considered appropriately drastic to set back vigorous competing vegetation, at least in the scarified trails. At the same time, planting spots can be found without further modification. Its main advantage is that it is far less costly than multiple treatments, and thus the rehabilitation budget can be stretched to cover more hectares. It also creates planter access. Treatments are cost-effective on accessible backlog sites, at least in the short-run. An attempt should be made to orient V-plow trails north-south, so that both sides receive insolation. On east-west trails, seedlings planted on the south (north-facing) side may be doomed to poor growth and low survival (Case Study 15, Appendix 1).

Disadvantages

The effective use of plows is largely limited to current NSR blocks, and as increasing emphasis is being placed on backlog sites which carry more successionaly advanced vegetation, the use of V-plows appears to be decreasing. At the present time, the use of plows as a rehabilitation tool has been too recent for adequate assessment. Use of this implement in more advanced brush, however, has had mixed results (Case Studies 6 and 15, Appendix 1), at least partly because of shading and overtopping from shrubs and trees established between the trails. Other problems include hardwoods falling back into the trail, and the unplowed area serving as a refuge for rodents which clip newly planted seedlings (J. Perry, pers. comm.).

4.6 Old Logged Openings (Deciduous/Conifer)

Old Intermediate Utilization (I.U.) logged areas receive high priority in rehabilitation programs if they are near mills, accessible and treatable (M. Bruhm, pers. comm.).

If the sites contain sufficient merchantable timber (e.g., more than 140-150 m³/ha, although this varies from district to district), then a timber sale can be negotiated with a local contractor or company, possibly with some subsidy in the form of minimal stumpage rates, to make the sale more palatable (F. Newhouse, pers. comm.). In this case, logging in the leave-strips can accompany the brush-clearing activities in the logged strips.

If the volume of residual timber is too small, or if it is diseased or otherwise of poor quality, the remaining rehabilitative option is to clear the site and plant. Knockdown has been accomplished by blades or by cables. For example, in the Lakes Forest District, knockdown of diameter-logged I.U. stands has been carried out using a cable behind two D-8 crawlers. Subalpine fir and cottonwood residuals with diameters up to about 35 cm have been knocked down in this fashion (K. Van Tine, pers. comm.). Operators can use slope to their advantage in cabling down large trees.
When these operations are completed, the entire I.U. block can be treated as a whole. Potential treatments include broadcast burning, pile and burn, brown and burn, and, of course, the full spectrum of secondary treatments if required.

The feasibility of a broadcast burn is very much dependent on the quality and distribution of fuel. Harvesting of merchantable timber may eliminate the potential for a broadcast burn, if insufficient fuel is left on the site. If a broadcast burn is felt to be the best treatment, falling but not harvesting the residuals may be the better option. As in other regions, residuals can be felled so as to maintain an even distribution of fuel.

In I.U. logging, diameter or selection logging is also included, leaving, smaller and/or less desirable trees. Clearance options are essentially the same as in strip-logged I.U. stands, except that residual falling may leave a more continuous slash, thus widening burning opportunities.
5 MICROSITE PREPARATION

5.1 Introduction

Once brush clearance has been accomplished as a first phase of rehabilitation, preparation of planting microsites is frequently necessary. However, rehabilitation on some sites may not require separate operations for brush clearance and microsite preparation. It may be found that brush clearance alone produces sufficient planting spots or affords a suitable seedbed. Similarly, certain site preparation treatments may provide sufficient freedom from competing vegetation, so that an initial brush clearance operation is not necessary. In most backlog situations, in which a substantial degree of brush competition is present, microsite preparation will be a necessary prerequisite for planting.

In north central British Columbia, options for site preparation are potentially wide, encompassing prescribed burning, a range of mechanical treatments, and various chemical and combination treatments. The biological objectives of site preparation vary considerably across the area, according to the gradients discussed in Chapter 2. Therefore, treatments deemed effective in one subzone are not necessarily effective in an adjacent one. Furthermore, the range of treatment options is constantly changing. New machines are being developed, others are being discontinued. Recent developments may be judged on superficial merits, such as the initial appearance of a treated block. The real test, namely establishment of a well-stocked, freely growing stand, may not yet have been properly assessed. On the other hand, promising new developments may be deferred because of over-caution on the part of conservative managers. New treatments may not initially receive optimum application; in some cases, several years may be required before their real value can be recognized. A bad first impression can be lasting.

In this section, the advantages and disadvantages of various site preparation techniques are reviewed, and related to site characteristics. Methods are classified according to their biological objectives, following the format in the Silviculture Manual, Chapter 5 (B.C. MOFL 1985b).

Figures 14 and 15 show historical site preparation methods by regions. Figure 14 compares the two major zones (SBS and BWBS) in the study area; Figure 15 compares the site preparation history of the Prince George, Prince Rupert, and Cariboo forest regions in the SBS zone. Data were obtained from history records as of November, 1986.

5.2 Prescribed Fire

5.2.1 General considerations

Prescribed burning has not been extensively used in rehabilitation, mainly because of the less favorable fuel characteristics of backlog, as compared to current sites. Nevertheless, because prescribed burning has such important implications for subsequent backlog conditions, its characteristics should be understood.

Burning is used as a site preparation technique throughout the SBS zone and sporadically in the BWBS zone. Most broadcast burning is carried out in preparation for artificial regeneration of spruce and, to a lesser extent, pine. It is the predominant form of site preparation for planting in north central British Columbia.

Seedling performance

Seedling performance following outplanting in suitably burned sites is widely believed to be superior to that on mechanically treated sites, although data are lacking (B. Bye, pers. comm.). In reviewing plantation performance in the Prince George Forest Region, Draper (1983) found that the 14 “best” plantations were all burned. This in part reflects the fact that fully 88% of the 173 plantations he sampled were burned.
FIGURE 14. Comparison of the percentage use of various methods of site preparation in the BWBS and SBS zones of the northern Interior. The area of the circle corresponds to the total area on which site preparation had been conducted up to and including 1986.

The main reason for inconclusive evidence supporting this observation is the variability in prescribed fire impacts and the lack of statistically valid comparisons (R. McMinn, pers. comm.). Attempts to quantify the effectiveness of burning (or any other site preparation) by assessment of existing plantations are complicated by variability in treatment application as well as in numerous other factors (e.g., weather
conditions during and following planting, and phenology of vegetation). A standard methodology for assessment of prescribed fire impacts is, however, now available (Trowbridge et al. 1986) and should improve assessment in the future.

Overall, the treatment is considered to be, on suitable sites, the cheapest and most effective option (B.C. MOFL 1985) especially since it also may provide good slash reduction, planter access, disease control and a certain degree of vegetation control.
Drawbacks

Prescribed burning, like all other site preparation treatments, has drawbacks. Its major limitation is control. Although the cost of broadcast burning compares favorably with that of other treatments, that cost carries a risk of escalating enormously if anything goes wrong. Many managers, understandably, are not prepared to undertake that risk. Fear of escapes has led to a paucity of experience with prescribed burns in some areas, such as the BWBS (B. Wesleyson, pers. comm.). However, the risk associated with burning can be minimized by careful planning and the use of appropriate techniques. Small areas, especially, may be difficult and costly to burn.

Uncertainty

Successful completion of a prescribed burn cannot be guaranteed. The satisfactory execution of a broadcast burn is highly dependent on a number of climatic and site-specific factors which are beyond the control of forest managers. Burning windows may be too narrow to treat all the blocks which carry burning prescriptions (B. Bye, pers. comm.). Ideal conditions are required to perform a successful burn. If the duff moisture level, for example, is too high, the burn may ignite and spread, but intensity will be low and objectives may not be satisfactorily met. If, on the other hand the moisture level in the duff is too low, an excessively high impact burn will take place, which may lead to site degradation and thus nutrient and erosion problems.

Potential site degradation

Site degradation can result from prescribed burning. Fear of long-term productivity loss precludes the use of prescribed fire on sensitive sites. For example, burning should be avoided on xeric ecosystems where much of the nutrient capital is concentrated in the duff layer (Pojar et al. 1984). Guides for identifying sensitive ecosystems are available in British Columbia (e.g., Klinka et al. 1984): these warn against burning sites vulnerable to erosion when mineral soil is exposed (steep slopes, erodible soil), or where loss of nutrient pool or water-holding capacity will detrimentally affect stand development. In general, broadcast burning is suitable for mesic and wetter sites in most subzones, where block design, slash loads and duff layers permit. However, within each subzone there may be disagreement about such matters as the threshold values of duff thickness at which broadcast burning may be allowed (B. Hawkes, pers. comm.).

Nutrient depletion

Although nutrient depletion takes place following slashburning, evidence of long-term effects on tree growth is contradictory (Feller 1982). In the northern Interior of British Columbia, Ballard (1984) found that the frequency and severity of a number of nutrient deficiencies were greater in young spruce trees growing in plantations that were either mechanically treated or slashburned, than in plantations that were untreated. Growth, however, was better in the former plantations, suggesting that the improved conditions afforded by these treatments more than compensated for the loss of nutrients.

Insects and disease

Black army cutworm (Actibia tennica) is a multiple host pest which attacks young plantations throughout British Columbia. The heaviest concentrations appear to occur on openings burned during the previous 1 or 2 years (Ross and Ilntyski 1977). For example, 10 of 31 plantations in recently burned openings in the Morice, Lakes and Bulkley TSA’s were affected in 1985 (Wood and Van Sickle 1986). As a consequence, planting programs may be delayed, or site preparation methods other than prescribed fire may be employed.
Also associated with prescribed fire is the rhizina root rot (*Rhizina undulata*), which may affect seedling survival during the first growing season. Incidence of this fungus is, however, rather low in the SBS and BWBS zones (e.g., Wood 1986).

**Brush control**

One of the major advantages of burning as a site preparation is brush control. A high impact fire will usually set back competing vegetation for several years, creating a competition-free window in which spruce or pine seedlings can establish and attain a free-growing status. However, the degree to which brush control is effected is highly variable, depending on intensity of burn, site conditions and brush species. Low impact burns which do not destroy the majority of weed rhizomes may in fact exacerbate the brush problem on a site (see, for example, Case Study 9, Appendix 1). In general, fire has its greatest effect on underground storage organs in the spring when carbohydrate reserves are at their lowest and thus most vulnerable (Cleary et al. 1978). Unfortunately, in north central British Columbia, early season burns seldom achieve an adequately high impact on moist sites (B. Hawkes, pers. comm.).

**Aspen**

A number of brush species are ecologically adapted to regenerate after fire. Aspen (*Populus tremuloides*), for example, is known to sprout vigorously following fire (Haeussler and Coates 1986). Burning can therefore aggravate aspen competition where it forms part of the pre-logging stand.

**Fireweed**

Fireweed rhizomes will be killed by high impact burns, but due to its prolific capacity for seeding, it can colonize burned blocks quickly and may establish a dense cover within as little as 1 year. Except at the end of the growing season, fireweed has a high moisture content and, hence, low flammability (Sylvester and Wein 1981, cited in Haeussler and Coates 1986).

Low impact burns can stimulate fireweed growth. On one mesic site in the Morice District (SBS1), a broadcast burn had escaped into an adjacent area in which the slash was not heavy enough to carry a very intense fire. Within 1 year, fireweed was over 1 m tall, and smothering spruce seedlings. It seems likely that the burn was not enough to kill the fireweed rhizomes, and vigorous sprouting took place the following year.

**Reedgrass**

Reedgrasses (*Calamagrostis* spp.) can also constitute a competitive threat following fire. These plants are tolerant of burning, as well as capable of prolific seeding-in following fire (Haeussler and Coates 1986).

**5.2.2 BWBS**

Historically, prescribed fire has not been an important site preparation option in this zone. A total of 4606 ha (or 5.67% of the total open area to 1986) has been treated by broadcast burning in preparation for planting. On a percentage basis, burning is prescribed less often here than anywhere else in the study area. Conversely, wildfires account for fully 16% of the total area disturbed, much higher than in any other region (Fig. 14). The higher incidence and/or extent of wildfire can be attributed to the more continental climate experienced in this area, characterized by warm, relatively dry summers and consistent winds. Natural fire is an integral part of the dynamics of boreal forest ecosystems (e.g., Annas 1983), perhaps even more so than forest ecosystems west of the Rockies.
Managers have been reluctant to use prescribed fire in the BWBS because of difficulties with control (e.g., H. Krawczyk, pers. comm.). However, several interviewees expressed a desire to increase the use of prescribed burning as a site preparation tool (B. Wesleyon, pers. comm.).

If aspen or reedgrass form part of the pre-logging ecosystem, a low impact fire can stimulate one or both of these species to the extent that they will pose a hazard to newly planted seedlings (L. Herring, pers. comm.).

Burning was also seen as an important alternative to mechanical treatment on steep, inoperable slopes, and on sites with heavy slash or deep duff (W. Thorp, pers. comm.). These sites need to be identified before logging is carried out, so that appropriate planning is undertaken (G. Cissel, pers. comm.).

5.2.3 SBS (Group 1: SBSj1, j2, f, and n; "wet" units)

Broadcast burning is both the most popular and most widely practiced treatment for site preparation in this area. For example, in the Prince George East Forest District, about three-quarters of all treated openings were broadcast burned in 1985 - although not all of these were intentional (B. Bye, pers. comm.). Most silviculturists interviewed indicated that they would like to see more prescribed burning. Furthermore, most felt that survival and/or initial growth were superior following burning compared to mechanical treatment. Burning was identified as a strongly preferred treatment on steep slopes or moist, fine-textured soils where mechanical treatment is inefficient or liable to lead to site degradation.

Broadcast burning, according to the History Record System, has evolved from the early 1970's, when the primary objective was hazard reduction, to the present time when the primary objective is planting spot preparation. Hazard reduction and planter access are still, of course, important benefits. Target impacts need to be high enough to reduce duff depth sufficiently to provide planting spots, as well as to set back competing vegetation. Increasing effort is now being placed on improving local skill at identifying, then achieving, the desired impact on any particular site (B. Hawkes, pers. comm.).

Obtaining a high enough impact on wetter sites and a low enough impact on drier sites is a problem (P. Sears, pers. comm.). Planning and executing a burning program can be very difficult if windows are narrow (F. Gunderson, pers. comm.). Duff moisture levels are seldom low enough in subhygic and hygic ecosystems to allow adequate heat penetration below the surface to consume duff or to kill the roots of competing vegetation. On these sites, ignition is not so much of a problem as is obtaining the desired impact (N. Crist, pers. comm.). Inadequate duff consumption may result in a persistent brush problem. It has also been noted that on hygic sites, fuel loads may be thin and scattered, further reducing the opportunities for burning (B. Richards, pers. comm.). To achieve higher impacts on wetter sites, burning in July and August may be necessary (D. Presslee, pers. comm.). A number of licensees have recently carried out summer burns with good results and no major escapes (N. Crist, pers. comm.).

The Prescribed Fire Predictor (Muraro 1975) is widely used and generally considered satisfactory. On spruce-balsam slash, the type commonly encountered in this area, it tends to under-predict reduction in slash (<22 cm), but predicts duff consumption to within 20% (Lawson and Taylor 1986).

5.2.4 SBS (Groups 2 - 5)

Questionnaire respondents generally indicated that in this area, prescribed burning was the “most successful” and “should be used more frequently.” One respondent, specifying the SBSj2 variant, stated that 90% of seedlings planted on burned sites are freely growing after 7 years, whereas the corresponding figure for windrowed sites was only 40-50%.
Dependence on the use of prescribed fire varies considerably over this area, depending on climatic and ecological conditions (i.e., burning windows), personal preference, and experience. Burning windows are generally wider here than in the wet biogeoclimatic units of Group 2. Some interviewees included broadcast burning as a treatment falling out of favor because of problems with control (B. Walker, pers. comm.). In general, treatment costs are lower than alternative means of site preparation, but some respondents indicated that these did not take into account the risk of escape. Many respondents stated the need for "high impact burns" on wetter sites that usually required summer ignition. However, such burns are potentially risky. In 1986, for example, a number of expensive escapes occurred in the SBSe2 near Carp Lake, resulting from mid-summer burning (B. Baker, pers. comm.).

Burning of mesic and drier sites can possibly lead to nutrient deficiency problems later (see Case Studies 23 and 24, Appendix 1). In a study 90 km north of Houston (SBSe1), Taylor and Feller (1986) examined nutrient losses on mesic (01) and subhygric/hygric (08-09) sites. The mesic site suffered substantial losses of nutrients under low and moderate impact classes, ranging from 56% of total sulphur to 33% of total magnesium in the slash and forest floor. Losses on the subhygric/hygric site were much less. In the SBSe2, spruce planted on sites that had been severely burned are showing severe magnesium deficiency, despite good initial survival and growth (P. Sears, pers. comm.).

In the southwestern portions of the Vanderhoof District (SBSe1 and i), a secondary mechanical treatment, such as mounding or disc trenching, has been used as a follow-up to burning (either prescribed or accidental). The primary objective of the prescribed burn was to reduce logging slash, and not to consume duff layers. Thus, burning windows were widened, since burning could go ahead even at high moisture levels. Although this treatment was applied to a recently logged site, it may have application to backlog sites.

5.3 Scalping

Scalping is the removal of the duff and humus layers, and the exposure of underlying mineral soil. The purpose of this practice is, first, to warm up mineral soils, thereby allowing root egress and minimizing planting shock; and, second, to eliminate competing vegetation. In the northern Interior, scalping treatments include blade scarification, V-plowing, brush blading (depending on the manner of operation), patch scarification and disc trenching.

5.3.1 Effects on seedling performance

Scalping, or screeing, has been shown to significantly improve the performance of planted spruce (Lees 1972; Stiell 1976). In one trial (McMinn 1985d), spruce seedlings planted on scalped sites were more than 60% taller than seedlings on untreated sites. However, performance of planted stock on scalped may be inferior to that on mixed or inverted microsites (McMinn 1985a).

The effectiveness of scalping in preparing a site for growing spruce or pine is very much dependent on the nature of the underlying mineral soil (B.C. MOF 1985). Where soils are medium to coarse textured, scalping exposes a rooting medium with favorable physical characteristics, allowing unimpeded root extension (R. McMinn, pers. comm.). This, in combination with an improved thermal regime, may sufficiently compensate for lack of nutrients. In time, roots can extend into adjacent undisturbed areas and there tap nutrients for continued growth.

Scalping would be an inappropriate treatment in soil with unfavorable physical characteristics, for example, Luvisolic soils developed in fine-textured glacio-lacustrine parent materials. Planting in scalped soil under these conditions may lead to poor root extension and possible frost-heaving.

On the other hand, scalping coarse-textured soils (such as sands) may result in such poor nutrient and moisture retention that the improved thermal regime cannot compensate (Ezell and Arbour 1985; McMinn 1985a).
Scalping can effectively remove the roots of competing vegetation, thereby providing a competition-free window of up to several years for the establishing seedling. It is most commonly used in the wetter biogeoclimatic units of the SBS (i.e., the j1, j2, o, f, and moist ecosystems of the e2), where vegetative competition and low soil temperatures are the primary obstacles to seedling establishment.

5.3.2 Methods

5.3.2.1 Blade scarification

Blade scarification is normally carried out using the angling blade of a bulldozer. It therefore has the advantage of freely available equipment and operators. The preparation of biologically suitable microsites by blade scarification has been extremely variable, due to the wide range of operator skill and objectives, site conditions, and equipment used. The use of blades may be inefficient because of the difficulty in dispersing slash. On sites in which slash loading is heavy, blade scarification may involve frequent reversals to unload debris.

5.3.2.2 V-plows

V-plows are used on sites with moderate to heavy slash, preferably on slopes less than 30%. They have been used as an alternative site preparation treatment where burning is either not feasible or was attempted with poor results.

The V-plows produce an effect similar to blade scarification, but because of the plow sole and the “V” shape, more mixing on the berms theoretically takes place. Plowing sometimes results in too much movement of soil, but too little mixing of organic material with mineral soil (S. Knowles, pers. comm.). The degree of soil disturbance in the trail is highly variable, depending on the skill and objectives of the operator. The difficulty in matching scalping depth to site conditions is a widespread limitation. Operation on moist sites leads to considerable rutting, and seedlings planted on the trail are frequently subject to flooding (Case Study 6, Appendix 1; Fig. 16).

Disadvantages include the great weight of the implement (which can vary between 2000 and 3000 kg, or up to 3600 kg for the C&H plow). As this weight is forward-mounted on the crawler tractor, traction is sometimes adversely affected, especially on wetter sites (R. McMinn, pers. comm.). The size of the implement makes it unwieldy. The length is particularly disadvantageous, especially on uneven terrain, where gouging is virtually impossible to avoid (R. McMinn, pers. comm.). The design of the plow is variable, having been modified and adapted by several users in the northern Interior.

In general, efficiency is greatest where machine operation is not hindered by broken terrain, closely spaced stumps, and full-tree slash (B. Walker, pers. comm.). Operation is seen to be more difficult on winter-logged sites because of greater stump height. Trails are normally created along the contour on gentle slopes (up to 15-20%, depending on operator) and directly up- and downslope on steeper sites. Consequently, operation on slopes above 25% is not recommended (Coates and Haeussler 1984) because of excessive erosion and site degradation. Furthermore, production efficiency is drastically reduced because operation is only possible on favorable grade, meaning that the machine plows downslope, and “walks” back.
FIGURE 16. V-plow rehabilitation on a subhygric to hygric (05) ecosystem (spruce-horsetail) in the Mackenzie Forest District (SBS12). This spruce seedling, planted in the trail, was killed by flooding. (Case Study 6, Appendix 1).

Microsite selection

Planting in the trail itself was common until fairly recently: those seedlings are now frequently dead or in poor condition (see Case Studies 2 and 6, Appendix 1). However, R. McMinn (pers. comm.) has observed a V-plowed site on silty loam with a thick Ah horizon, in which spruce (planted in the middle of the trail) were stunted and slow-growing at age 5, but had recovered by age 10.

In sites where scalping treatments have caused rutting or compaction, planting microsites are restricted to the suitable parts of the berm of mixed mineral and organic soil on either edge of the bladed trail. Planting on top of the berm may not be desirable, because of looseness of the soil and competition from vegetation (R. McMinn, pers. comm.).

Selection of planting microsites appears to be critical (Case Study 7, Appendix 1). Closer supervision and instruction are becoming the norm (B. Williams, pers. comm.), with planting restricted to carefully chosen spots on berms.
Brush control

Brush control by V-plows received a variable rating, depending on different experiences on different sites. Most respondents perceived that V-plowing affords better and longer lasting brush control than other treatments (e.g., windrowing). This is substantiated in one case by Herring (1981) who found that brush was somewhat less following C & H-plowing than following treatment with sharkfin barrels.

There appears to be a potential for trails to seed-in to Sitka alder (A. viridis), willow, birch, and cottonwood over time, even where compacted and degraded, and that these may later interfere with the achievement of free-growing status. Exposing substantial areas of mineral soil will probably lead to later brushing-in by these species if a seed source is present (R. McMinn, pers. comm.).

Long-term effects

Little documentation on the long-term effect of this degradation on seedling growth is available. In the southern United States, Ezell and Arbour (1985) found that differences in organic matter content between V-plowed and untreated microsites persisted after 10 years.

Summary

In summary the disadvantages of using plows for scalping are:

1. exposure of mineral soils to frost-heaving (in susceptible soils);
2. risk of flooding or saturation in depressions;
3. difficulty in controlling scalping depth;
4. inconsistent microsite creation;
5. nutrient depletion; and
6. risk of site degradation.

5.3.2.3 Ripper plow

The ripper plow is used almost exclusively on frozen soil on sites that are inaccessible in summer. Inaccessibility can be due to lack of summer access or poor on-site tolerance of heavy traffic. Details are given in Coates and Haeussler (1984). The implement is used in both SBS and BWBS zones, but in 1986 was more extensively used in the latter.

The plow consists of a ripper tooth and cutting edge, and moldboards that disperse the clods on either side. It was designed to create a trench approximately 50 cm deep with raised berms on either side (Coates and Haeussler 1984).

In practice, the size and shape of the trails were observed to be highly variable because of surface roughness and slash. The tooth shatters the frozen soil into hard clods of various sizes, which then settle during the following summer into heaps and mounds. Depending on the design of the moldboard plow attached to the tooth, some of these clods may roll back into the trench (B. Wesleyson, pers. comm.).
The degree and rate of settling depends on the moisture content of the clods. If nearly saturated, a high degree of deformation to the berms and trench may take place following snowmelt. This appears to be a major limitation on subhygric and hygric sites in which extensive settling has eliminated much of the initially raised microsites. Alternatively, clods created in fine-textured soils may require a prolonged period in which to break down.

On moist sites, the creation of trails directly up- and downslope facilitates drainage, an important secondary benefit. However, trails on moderate slopes (> 10%) in areas of silty soils may experience severe erosion and loss of planting sites. In such cases, intermittent lifting of the plow is recommended (Coates and Haeussler 1984). Normally, one plow attachment is used, thereby creating one trail per pass of the prime mover. Width of the trail is variable and depends on the implement that has been adapted by each user. Peace Wood Products uses a twin plow, thus creating two trails per pass (C. Kowalski, pers. comm.).

Coates and Haeussler (1984) report that the ripper plow was rated good to excellent for reducing grass and brush competition. However, trails examined in the course of this project were frequently so narrow that only a minimal brush-free swath was created. Grass and brush on undisturbed ground on either side of the trails had commonly overcome planted seedlings.

Heavy slash loads can interfere with operation of the ripper plow. It has been suggested that the prime mover be equipped with a brush blade to disperse slash on first-pass treatments (C. Kowalski, pers. comm.). The ripper plow is frequently used as a second-pass site treatment following windrowing.

Questionnaire respondents rated the ripper plow as both the best and worst treatment, and this disparity is probably explained by the range in plow designs and types of sites treated. It would appear to be best suited for medium-textured soils on gentle slopes, where drainage would be beneficial. A trade-off needs to found between size and shape of moldboard (for adequate creation of planting spots) and power requirements of the implement. For proper vegetation control, bigger is better, but available prime movers can accomplish only so much, especially in frozen ground. The sites on which ripper plows are usually prescribed have few alternatives in the way of mechanical treatment.

5.3.2.4 Brush blades (windrowing and piling)

The use of brush blades to clear large debris into rows can be considered a form of scalping. Spot piling ("rough-bunching") is a closely allied treatment. The choice of spot piling or windrowing is dictated by site characteristics and personal preference. For example, spot piles can be packed more tightly so as to allow a more effective burn (G. Cissel, pers. comm.).

This treatment is one of the most commonly practiced in the study area (about 10% of disturbed area was windrowed and piled) according to history records. Formerly, straight blades were used to accomplish this operation, but because of excessive loss of topsoil, they have been largely replaced by brush blades.

The brush blade is intended to "float" over the ground surface, to move heavy debris while simultaneously creating scalped planting spots as the tines move through the soil (Coates and Haeussler 1984).