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Tree Growth on Rehabilitated Forest Roads in Southwestern British Columbia: Year 8 Results

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INTRODUCTION

Rehabilitation of forest roads, combined with reforestation, can be an effective strategy for increasing timber production on managed forest lands. Restoring soil conditions on roads that probably would not otherwise support tree growth, increases the amount of land available for growing trees. However, to realize the full benefits of soil rehabilitation efforts on forest roads in British Columbia, reliable and cost-effective methods need to be established.

In parts of interior British Columbia successful forest establishment and growth were observed after decompacting the soil on forest landings and then planting lodgepole pine (Plotnikoff et al. 2002; Bulmer 2000). But, information about the longer-term benefits of rehabilitation efforts is lacking. Stocking levels and site index evaluation based on tree growth rates are required for a range of site types to determine if soil rehabilitation efforts are cost effective.

In 1994, a study was established in coastal British Columbia to evaluate operational road rehabilitation (Hickling et al. 1995, 1996). At Year 8, in the summer of 2002, tree stocking and growth were evaluated on 25 of the 73 original plots, along with soil conditions, vegetation recolonization, and competition. This report describes the broad range of plot conditions as observed in 2002, provides an update on the success of the rehabilitation efforts, and presents some new information about the factors that appear to have affected tree growth on the rehabilitated sites.

METHODS

Sampling Design

In the original study, 73 plots were established over two years, in eight biogeoclimatic subzones, on road sections where forest companies had applied a range of soil rehabilitation measures and had planted commercial tree species. No attempt was made to establish replicated experimental plots. Despite the consequent inability to test for treatment differences, the sampling approach had the following advantages:

1. It allowed a broad range of site types and operationally relevant treatment techniques to be evaluated (based on a description of issues and needs prepared by Scagel et al. 1993).

2. It encouraged active participation from a large number of forest industry cooperators.

3. It provided information quickly, at a level of detail and reliability that was appropriate to the time, i.e., when road rehabilitation was new to coastal forestry.

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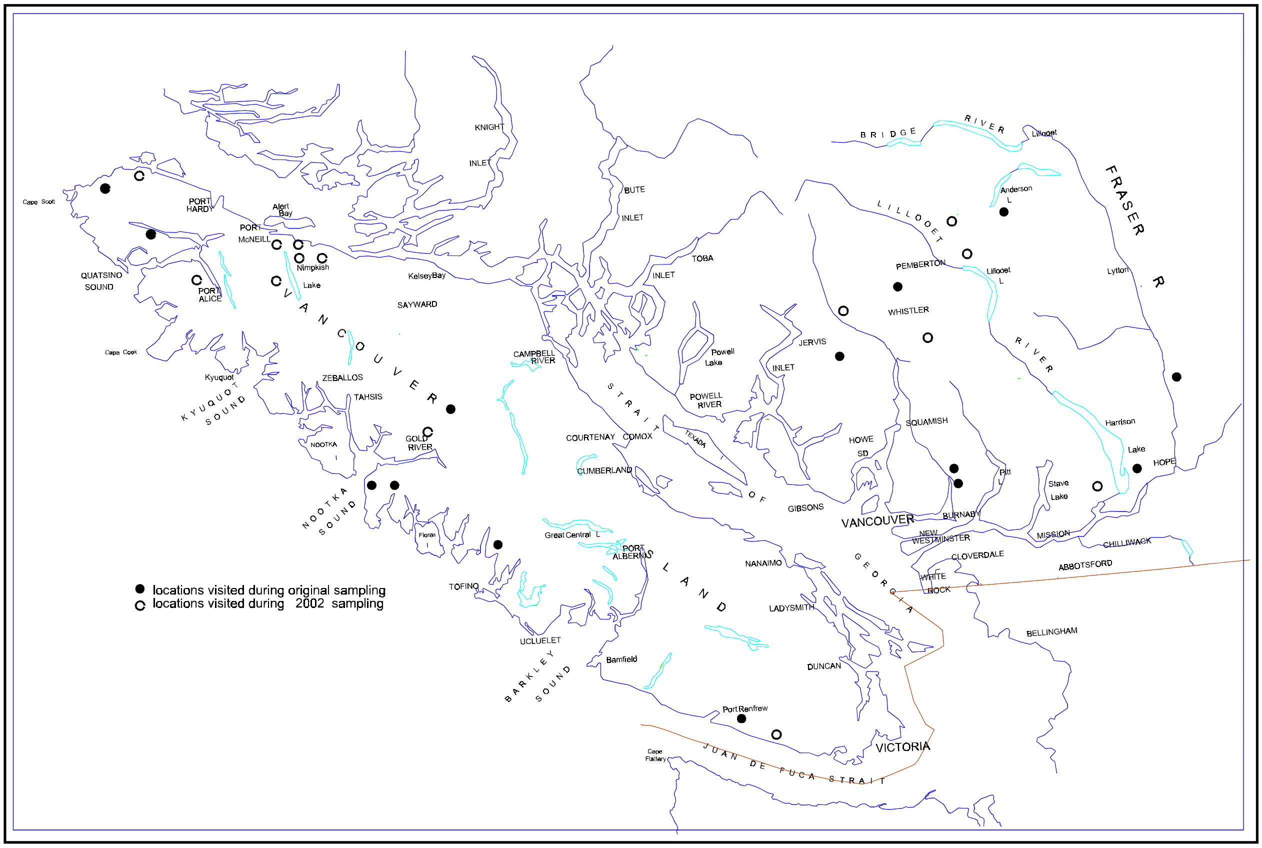

Figure 1. Map of the study area, showing plots from the original study, and plots revisited in Year 8 (2002).

To select the 25 plots for re-evaluation in 2002, we focused on areas with good road access where a large number of plots had been installed in a particular biogeoclimatic unit. Within each area visited, we sampled all locations, regardless of planted tree species, regeneration performance, stocking levels, or other factors. Twenty-four of the locations we visited were located in the Coastal Western Hemlock (CWH) biogeoclimatic zone, with half of those located in the submontane variant of the very wet maritime subzone (CWHvm1). Most of the roads we visited were planted with Douglas-fir or western redcedar; a smaller number of roads were planted with amabilis fir and yellow-cedar. Sites were located on Vancouver Island and adjacent areas of the mainland (**Figure 1**).

At each plot, three 0.005-ha circular subplots were established at random distances along the centerline of the rehabilitated road, either within the original plot, or along the identified road section. In each subplot, all surviving crop trees were tallied, along with tree height, and number of increments above breast height. Trees with forked, dead, damaged, or broken tops were recorded, but not included in height calculations. Non-crop trees or other species were tallied for each subplot, and the percent cover of understory species was also recorded.

Information was recorded about the cross section profile of the road, surficial materials, and presence of imported fill. Depth of decompaction was determined by probing with a planting shovel. Soil texture was determined by hand. Visual estimates of coarse fragment content, percent of the surface occupied by exposed mineral soil, and coarse woody debris were recorded, along with soil drainage, evidence of seepage, soil colour, depth of forest floor, and soil moisture and nutrient regime.

Soil moisture and nutrient regime are difficult to determine for highly disturbed sites, but we recorded expected values of these for each plot. The expected values could be used to estimate an "equivalent" site series, for comparison to undisturbed areas.

RESULTS

Soil Properties

Soil properties are described in **Table 1**. The roads were initially constructed with a variety of surficial materials, including morainal, colluvial, and glaciofluvial materials. Most of the road sections were also capped with imported rock and/or road base materials; decompaction and rehabilitation treatments often left the larger rock from the subgrade exposed, which reduced the soil rooting volume on some sites.

Forty-four percent of the roads visited were recontoured

Table 1. Site conditions for plots planted with Douglas-fir and western redcedar.

Plots, by species and subzone/variant	Substrate[a]	Road profile[b]	Coarse fragments (%)	Exposed mineral soil (%)	Decompact. depth (cm)	Drainage class[c]	Seepage present (y/n)	Soil moisture regime[d]	Soil nutrient regime[e]	Forest floor depth (cm)	Coarse woody debris (%)
Douglas-fir											
CWHvm1											
HG35	M	M	62	89	28	M-W	No	3.5	3	0.6	11
N801	FGIRRB	R	60	95	45	W-M	No	3.5	2.5	2	5
N802	FGIRRB	R	63	97	47	M-W	No	3.5	2.5	2	3
K540	CIR	R	83	99	12	W-R	No	2	2.5	0	1
K1000	IRRB	R	82	95	38	W	No	3	2.5	0	5
E74	MIRRB	R	73	99	17	M-W	Yes	3.5	2.5	1	1
N80	IRRB	F	85	99	10	W	Yes	2.5	2.5	0	1
CWHxm											
HI33	M	F	60	75	27	W	No	3	2.5	0	25
AC190	M	R	60	98	30	W	No	3	3	0	2
AC3	IRRB	FB	77	83	20	W	Yes	4	3.5	1.5	17
KH79	FG	F	70	95	35	W	No	2	2	0.6	5
CU301	M	FM	53	91	35	W	No	3	2.5	2	9
CU302	M	FM	53	82	37	W	No	3.5	3	2	18
CWHms1											
LL	M	F	37	97	23	M-W	No	3	3	1	3
CWHds1											
SQ1	CF	F	37	87	55	M-W	No	3	3	1	13
SQ2	CF	F	43	82	28	M-W	No	3	3	0	18
CWHdm											
HA	CFIRB	F	50	92	33	M	No	3	2.5	1	8
IDFww											
BK	CM	R	52	99	18	M-W	No	2.5	3	1	1
Western redcedar											
CWHvm1											
CE900	M	FM	50	80	47	W	No	3.5	2.5	0	20
CWHvm2											
TS24	M	FB	50	83	38	W-M	No	3.5	2.5	0	17
CWHvh1											
NW25	M	LM	57	98	50	W	No	3.5	3	1	2

[a] Substrate. M = morainal. FG = glaciofluvial. C = colluvial. CF = colluvial/fluvial. R = rock. IR = imported rock. RB = road base.

[b] Road profile. F = flat. L = landing. M = mounded. R = recontoured. B = berms.

[c] Drainage class. M = moderate. W = well drained. R = rapidly drained.

[d] Soil moisture regime. 2 = very dry to moderately dry. 3 = moderately dry to fresh. 4 = fresh to very moist.

[e] Soil nutrient regime. 2 = poor. 3 = medium. 4 = rich.

(i.e., sidecast materials were pulled back onto the road to re-establish pre-construction slope topography), while 28% of the road sections were flat. Twenty percent had flat profiles with some mounding, or were flat with berms along the side. Some of the plots with flat road profiles appeared to have incurred less decompaction and/or mixing during the rehabilitation process compared to the recontoured plots. Plot NW25 was a rehabilitated landing, with large mounds consisting of large woody debris and topsoil material mixed together.

Depth of decompaction was between 20 and 40 cm on 56% of the subplots, while 24% showed decompaction to a depth of 40 to 50 cm. Sixteen percent (four) of the subplots showed resistance to probing at <20 cm. Where decompaction depth was found to be shallow, it was often due to the presence of large coarse fragments. This likely created planting problems; on one subplot the trees were stabilized with mounded stones.

For most plots, soil texture ranged from sand to sandy loam, and coarse fragment content ranged from 50 to75%. Some of the plots with a higher coarse fragment content (>75%) also had very large boulders on the site.

Eighty-eight percent of the plots were well-to-moderately-well drained, and the plots either had no seepage, or seepage was minimal. The soil drainage characteristics were supported by ratings for soil moisture regime. Seventy-six percent of the plots were rated as moderately-dry-to-fresh or fresh. Only 20% of the plots were drier, with 4% (1 plot) rated as fresh to very moist.

Ninety-two percent of the plots had poor-to-medium or medium soil nutrient regimes. Plots with medium soil nutrient regimes often had topsoil or organic matter mixed with the rehabilitated road substrate. Those with a poorer nutrient rating were dominated by unweathered surficial materials from the original road surface.

Most of the plots had little to no forest floor, with the exception of thin organic horizons initiating under those plots with a high cover of red alder. With one exception, all of the plots had exposed mineral soil >80% or more of the surface, and <20% coarse woody debris. The coarse woody debris ranged from very small chunks of wood to large logs and stumps, but most of the plots had medium-sized woody materials.

Tree Stocking and Growth

Plots planted with Douglas-fir tended to have higher stocking levels than plots planted with western redcedar (**Figure 2**), but the results were variable (**Figures 3 and 4**) and no statistical analysis was performed on these data. Low stocking levels on some sites may reflect poor survival due to unfavourable soil conditions, climate, damage by wildlife, or other factors, which could have reduced stocking levels below the expected initial planting density of 1500–2000 stems/ha. Plantability could also have been a factor, as described by Scagel et al. (1993). The vast majority of trees we measured were planted, but in some cases natural regeneration might be expected to offset mortality.

On some plots, unfavourable soil conditions may have been a key contributing factor to low survival rates. For example, low stocking levels of Douglas-fir and western redcedar on plots K540 and N80 were associated with a

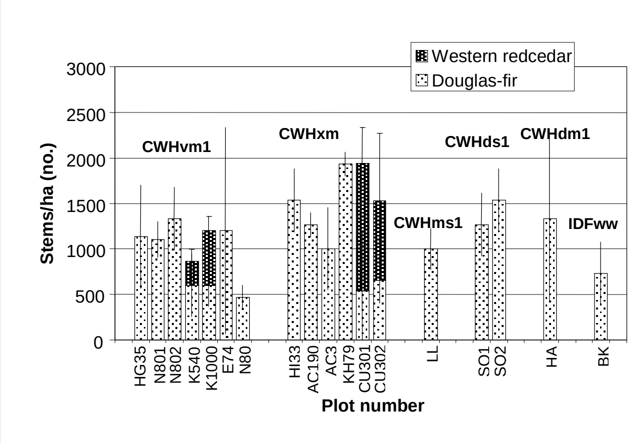

Figure 3. Stocking levels on plots planted with Douglas-fir. Western redcedar is also shown for plots planted with both species. Error bars represent 95% confidence interval of the mean for each plot (n=3 in most cases).

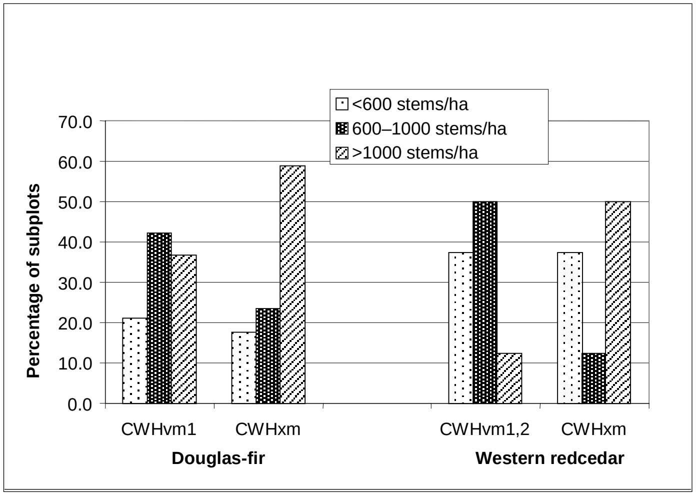

Figure 2. Stocking levels in the CWHvm1 and CWHxm for Douglas-fir and western redcedar.

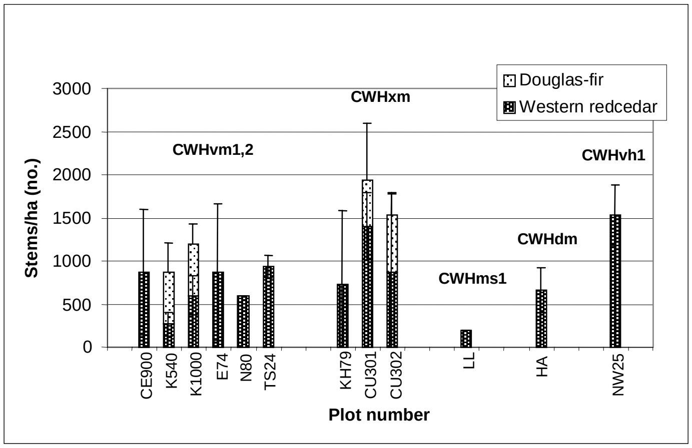

Figure 4. Stocking levels on plots planted to western redcedar. Douglas-fir is also shown for plots planted to both species. Error bars represent 95% confidence interval of the mean for each plot (n=3 in most cases).

Figure 5. Plot HG35 had good stocking and growth of Douglas-fir.

Figure 6. Low stocking levels and growth on plot K540 appeared to be related to a high component of large coarse fragments in the soil substrate, and limited decompaction. The site was located on a south-facing slope.

very high component of rock and larger coarse fragments in the rehabilitated soil substrate, and shallow decompaction of the road surface.

Total tree height of Douglas-fir and western redcedar appeared to coincide with the results for stocking in some, but not all, cases. For example, plot HG35 showed good stocking and growth of Douglas-fir (**Figure 5**), while results for both stocking and growth were poor on plot K540 (**Figure 6**). Sometimes, however, the stocking levels and tree heights diverged, with good stocking and less height growth (e.g., plot E74). In two cases (plot K1000 and plot N80, **Figure 7**), tree growth was exceptional for the few trees that had established, despite poor stocking overall. Lack of stocking success on these plots may have been related to quality of the soil and/or subsequent factors, such as browsing by elk.

Our results illustrate the importance of ensuring that the quality of the rooting medium following rehabilitation is the best the site can offer, so that early survival and establishment remain high. Subsequent success of the rehabilitation efforts would then be measured not only by high survival rates and rapid seedling establishment, but also by productive height and diameter growth of the planted trees.

Although data are not presented here, stocking and growth of both amabilis fir and yellow-cedar were disappointing. Soil conditions may have contributed to poor performance of these species on some roads, but on other roads the reasons for poor performance of amabilis fir and yellow-cedar were not clear.

Factors Affecting Success

Soils, Fertilizer, and Seeding. Early results showed that better tree growth was associated with soil organic matter (Hickling et al. 1996). However, for the subset of roads that we visited, only a very weak relationship was observed between soil organic matter content, as recorded by Hickling et al. (1996), and Year 8 height growth of Douglas-fir and western redcedar. Despite this, our results showed that plots with higher levels of coarse woody debris also had taller Douglas-fir and western redcedar trees.

Figure 7. Plot N80 showed low stocking levels of Douglas-fir, but trees that had become established were growing well. A high content of coarse fragments in the road substrate, combined with poor decompaction, likely contributed to poor survival on this site.

Site index of Douglas-fir growing on plots where seed and fertilizer were applied at the time of planting was evaluated using the growth intercept method (Nigh 1997), and compared to control plots where no further treatments were applied. In contrast to the results of Hickling et al., which showed improved early growth for fertilized sites, mid-term tree growth showed little difference

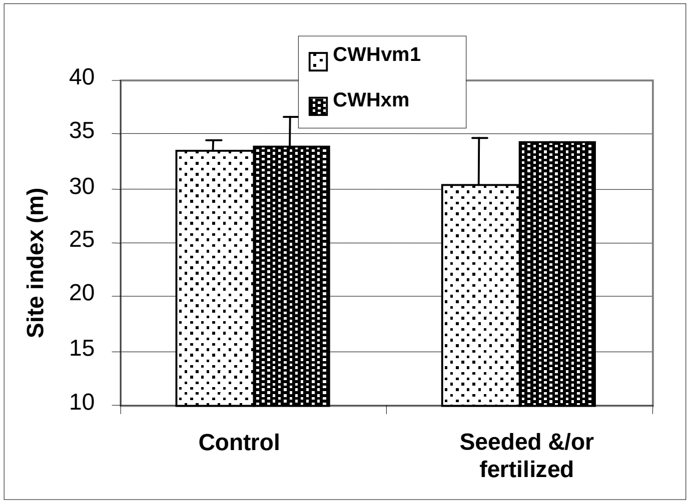

Figure 8. Site index for Douglas-fir on rehabilitated roads determined using the growth intercept method for trees with three or more years of growth above breast height. For the CWHvm1, n=2 plots for the control treatment (no seeding or fertilizing), and n=5 plots for the seeded / fertilized treatment. For the CWHxm, n=4 plots for the control treatment (no seeding or fertilizing), and n=1 plot for the seeded / fertilized treatment.

(**Figure 8**). These results suggest that the benefit of added fertilizer was confined to the establishment phase of seedling growth.

Average site productivity levels for Douglas-fir on the rehabilitated roads were near 32 m, which is similar to that for slightly dry site series in the very wet maritime zone (CWHvm1) and for slightly dry and wetter site series in the very dry maritime subzone (CWHxm). Our early results suggest that road construction and subsequent rehabilitation did not reduce site productivity to levels associated with drier sites, which may have been expected if the disturbance had resulted in greater site moisture deficits due to alterations of soil water movement.

Despite high variability, a combination of seeding and fertilizing appeared to have positive effects on grass cover (**Figure 9**), suggesting that the benefits of these erosion control measures may persist for eight years or more. No major trends were observed between grass cover and either stocking or growth of Douglas-fir. Plots with high grass cover after eight years included K1000 and NW25 (**Figure 10**). Both plots were characterized by cool, moist site conditions, which may have encouraged productive growth of the grass. The abundance of the grass on these sites did not appear to have affected tree performance directly, but damage by elk was a problem on plot K1000. The extent to which the forage on this site attracted elk is not known.

Species Selection. In the CWHvm1, western hemlock, red alder, and some western redcedar were the domi-

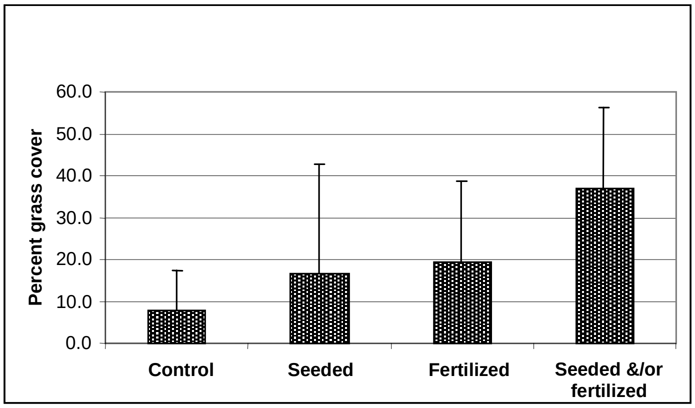

Figure 9. Percent grass cover for treated and control plots in all zones. High variation indicates that seed establishment varied for different plots. Error bars indicate 95% confidence intervals of the mean.

Figure 10. NW25 was a landing near Nahwitti Lake on northern Vancouver Island. Rehabilitation treatments included additions of topsoil and coarse woody debris, which likely contributed to the successful establishment of the grass and alder. The early establishment of grass and/or alder may have affected early growth of the planted western redcedar on this site.

nant regenerating species. In the CWHxm plots, we found similar species establishing by natural regeneration, although some of the plots in the CWHxm had more red alder and western redcedar. Plots in the CWHxm with high numbers of red alder also tended to be ones with low stocking for Douglas-fir, although the results were variable. Poor height growth and greater incidence of stem and leader damage on the Douglas-fir were also noted for many plots with high amounts of alder. The effect of the red alder on the height growth of the planted western redcedar was less apparent, although diameter growth and stocking rates were reduced.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

In an effort to determine the longer term benefits of forest road rehabilitation for seedling performance, a study was established in 1994 to evaluate operational road rehabilitation in coastal British Columbia (Hickling et al. 1995, 1996). At Year 8, in the summer of 2002, tree stocking and growth were evaluated on 25 of the 73 original plots, along with soil conditions, vegetation recolonization, and competition. The results indicate that, at most locations, road rehabilitation and reforestation resulted in adequate stocking of planted Douglas-fir and western redcedar (Forest Practices Branch 2002), and that tree growth was consistent with expectations for zonal sites in the CWH biogeoclimatic zone (Hunt 2002). Exceptions appeared to include those roads that had not received adequate decompaction, areas where the soil material consisted of a high proportion of large coarse fragments, or areas where alder had successfully re-colonized the sites to the detriment of planted conifers.

The importance of soil organic matter for plant growth is well known. Although correlations between height growth and previously determined levels of soil organic matter were mixed, our results showed that the presence of coarse woody debris was associated with better tree growth. And, we noted several examples of sites with incorporated topsoil that appeared to have better stocking and growth.

In order to realize the best results from rehabilitation work, roads should be decompacted over the running surface to a depth of at least 40 cm, while taking care to limit the exposure of large cobbles and boulders in the substrate, and the decompacted roads should be covered with topsoil and/or moderate amounts of small-to-medium-sized coarse woody debris.

Unless special management objectives allow alder to be considered as a crop tree, brushing would likely be required on some plots to protect the investment in conifer reforestation. Alternatively, seeding with a mixture of grass and legume species, particularly clover (Coates et al. 1993), could reduce the establishment and survival of red alder.

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