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TREE GROWTH ON SKIDROADS

On Steep Slopes Logged after Wildfires in Central and Southeastern British Columbia

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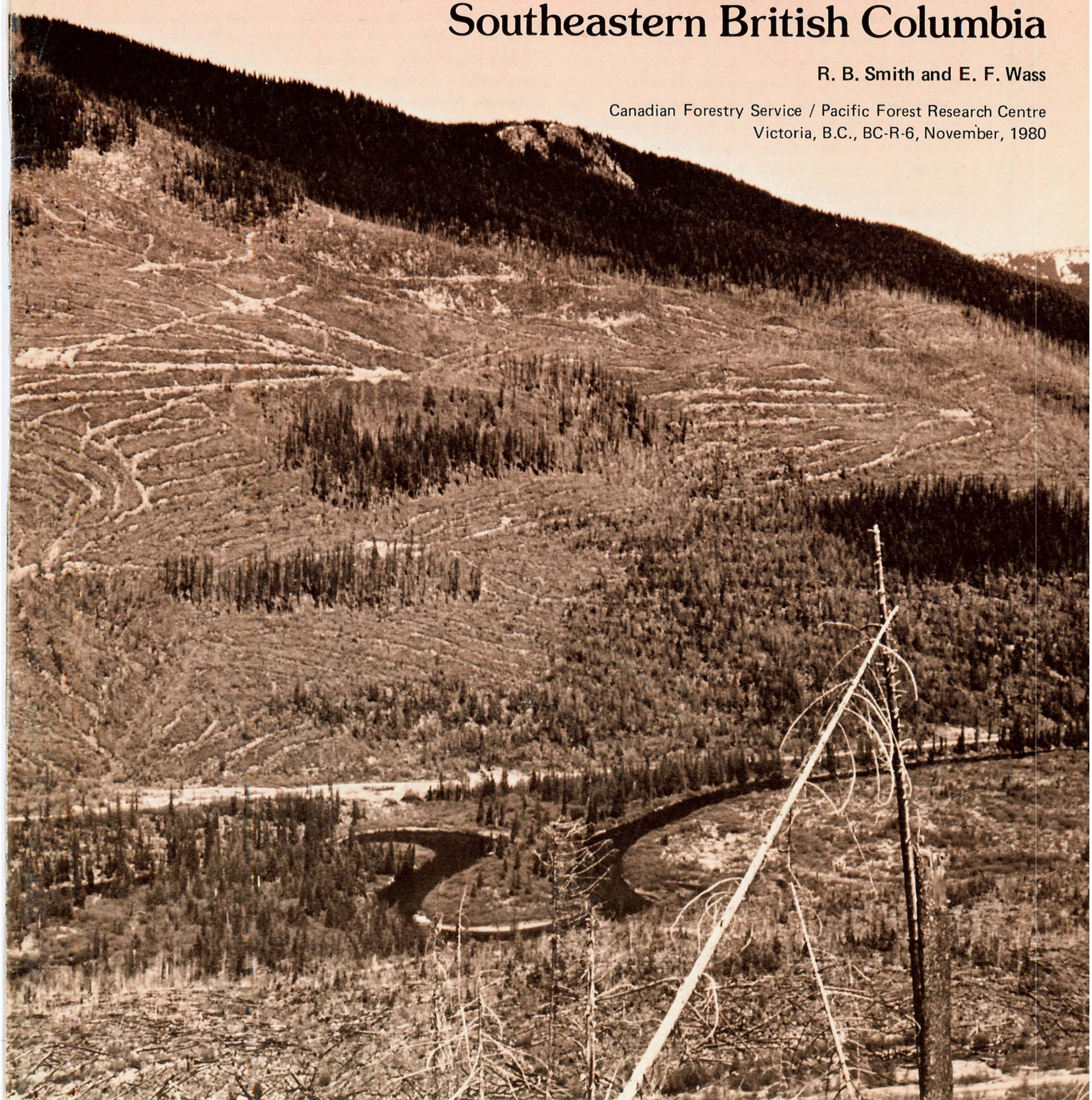

ABSTRACT

To assess growth of trees on contour skidroads, measurements of Douglas-fir, western larch, lodgepole pine and Engelmann spruce were taken 16 to 18 years after salvage logging of steep, wildfire burned areas. When compared with trees growing on adjacent (above and below) non-roaded surfaces, height-growth of trees growing on skidroad surfaces varied with species, soil and climate. In some sites, a considerable reduction in growth occurred on the skidroad surfaces; in one, the difference was not significant; in another, there was an enhancement of growth on a portion of the skidroad. When prorated over a whole clearcut, assuming a 32% coverage of skidroad surfaces, height-growth effects ranged from a reduction of 14.5% to an enhancement of 3.6%.

A system was devised to rate sites on their sensitivity to disturbance in terms of tree growth on the disturbed surfaces. In general, tree growth was reduced most on calcareous or strongly acid, coarse textured or shallow soils in wet climates. Least sensitive sites were those with slightly acid, non-calcareous, medium to moderately coarse textured soils in dry climates.

Attempts to determine the effects of skidroad construction on tree growth on intervening surfaces by comparing skidded and adjacent unskidded slopes were inconclusive. In one case, growth was significantly less on the skidded section; in two others no significant differences occurred.

RÉSUMÉ

Pour évaluer la croissance des arbres sur les chemins de débardage à niveau, des mesurages du Douglas taxifolié (*Pseudotsuga menziesii* [Mirb.] Franco), du Mélèze occidental (*Larix occidentalis* Nutt.), du Pin lodgepole (*Pinus contorta* Dougl. var. *latifolia* Engelm.) et de l'Épinette d'Engelmann (*Picea engelmannii* Parry) ont été effectués 16 à 18 ans après une coupe de récupération sur des terrains escarpés dévastés par des feux de friches. Comparée à celle des arbres venus sur des terrains adjacents (en amont et en aval) non utilisés comme voies de débusquage, la croissance en hauteur des arbres poussant sur les chemins de débardage variait en fonction de l'essence, du sol et du climat. Dans certaines stations il y avait une perte considérable de croissance sur ces voies; dans un cas, la différence n'était pas significative, dans un autre, il y avait gain de croissance sur une portion du chemin de débardage. Répartis sur l'ensemble d'un terrain coupé à blanc la proportion couverte par les chemins de débardage étant évaluée à 32% les effets afférents à la croissance en hauteur s'échelonnaient d'une perte de 14.5% à un gain de 3.6%.

Un système a été conçu en vue de coter les stations selon leur sensibilité à la perturbation en termes de croissance des arbres qui y poussent. En général, la croissance des arbres se trouvait réduite surtout sur les sols calcaires ou fortement acides à texture grossière ou peu profonds dans les climats humides. Les stations les moins sensibles étaient celles comportant des sols légèrement acides, non calcaires et à texture moyenne à modérément grossière dans les climats secs.

Les tentatives de détermination des effets de la construction de chemins de débardage sur la croissance des arbres dans les terrains intermédiaires, au moyen de la comparaison des pentes utilisées et des pentes adjacentes non utilisées comme chemins de débardage, n'ont pas été concluantes. Dans un cas, la croissance était significativement moindre sur la section utilisée pour le débusquage; dans deux autres, il n'y avait pas de différences significatives.

Cover: Portion of the 1971 Vunder Fire,
Horsefly River

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Fig. 1. A ground-skidded clearcut with skidroads built along the contour.

INTRODUCTION

Ground skidding is the dominant form of log yarding in interior British Columbia forests. On steep terrain, skidroads[1] are, of necessity, built mainly along or at a slight bias to the contour. The result, in effect, is a series of terraces spaced 20 to 50 m apart, the distance depending on stand, topographic and equipment factors (Fig. 1). On the average, over 32% of steep clearcuts ground-skidded on snow-free surfaces in central and southeastern British Columbia are composed of skidroad surfaces (Smith and Wass 1976; Schwab and Watt 1980). After completion of log skidding, these skidroads are not normally suitable for vehicular travel and the surfaces are thus available for tree regeneration. Stocking of trees on skidroads often reaches higher levels than on adjacent unroaded surfaces (Smith and Wass 1976), but often only after a delay of several years (Smith and Wass 1979).

A previous study showed that the growth of Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) on skidroad surfaces varied with position on skidroad, topographic aspect and soil chemistry, texture and depth Smith and Wass 1979). To enable greater input to the formulation of guidelines for ground skidding operations, studies have been extended to lower elevation, climatically warmer zones. Competition from residual trees and advance regeneration, a problem on logged but otherwise undisturbed surfaces, was avoided by sampling in areas salvage-logged after wildfires.

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1 The term *skidroad* is often used interchangeably with *skidtrail* (Conway 1976). We feel that the former term better describes the deeply cut roads usually associated with ground-skidding on steep slopes.

METHODS

Four areas salvage-logged after wildfires (Vunder, Gold, Pud and Galbraith) were identified (Fig. 2), which satisfied our general requirements; *i.e.,* adequate regeneration, yarding done on bare ground and a location at an elevation below the subalpine zone. Each area was burnt in 1960 or 1961 and each contained steep portions with contour skidroads suitable for sampling. The Vunder Fire provided five sites for study - two for comparisons of tree growth on skidroads and adjacent logged but otherwise undisturbed surfaces and three sites for comparisons of tree growth on undisturbed surfaces on adjacent skidded and unskidded slopes. In the two Vunder sites and in each of the three remaining burned areas, skidroad segments 15-25 m in length were selected and the closest post-burn regeneration tree per species to a point defined by randomly selected coordinates was sampled from each of five surface classes (Fig. 3): upper undisturbed, inner disturbed (cutbank + inner skidder track), middle disturbed (mid-road + outer track + berm), outer disturbed (sidecast or fill slope) and lower undisturbed. The width of the undisturbed surfaces was designated as 7.5 m (10.0 m in the Vunder Fire) above the cutbank and below the bottom of the sidecast. For each sample tree, species, age, total height, annual height-growth increments, as determined externally, and foliage color (Munsell Color Division 1972) were recorded. Trees younger than one-half the age of the fires were rejected, as were trees obviously damaged by animal browsing or rolling logs and windfalls. The number of skidroad sections studied and thus the number of trees sampled per study area varied, depending on the availability of suitable sites. For the five areas (two in the Vunder Fire) studied, the numbers of sections sampled ranged from 17 to 32. Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) was sampled in four of the study areas, Engelmann spruce in two, lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) in one and western larch (*Larix occidentalis* Nutt.) in one.

The annual height-growth data were analyzed by developing separate regression equations for each tree, using the general form:

$$Y\ (\text{height}) = (X\ [\text{age}] + 1)^b - 1,$$

where "b" was a regression coefficient. The regression coefficients, transformed to their natural exponentials for more nearly normal distribution, were subjected to the Student-Newman-Keuls' multiple-range tests (Zar 1974) to show any significance of disturbance class differences in growth rates. The model gave a good fit to the height data for each tree with a minimum coefficient of determination (r^2) of 0.97.

To determine whether the presence of contour skidroads affected tree growth by, for instance, diversion of seepage water (Megahan 1972), three locations with abruptly ending skidroads were located in the Vunder Fire. Random circular plots were established within the skidded and adjacent unskidded sections, with buffer zones provided to prevent sampling on skidroad surfaces and to allow a separation between skidded and unskidded sites. In two locations, plots were also established above the main skidded and unskidded sites in a burned-over but unlogged portion of the stand. In each plot, all trees over 1.25 m were counted and the height of the tallest tree of each species was measured. Non-pooled t-tests were used to test differences in mean heights of the tallest trees between the skidded and unskidded areas.

One to three soil pits were dug in each sample area; profiles were described and classified (Canada Soil Survey Committee 1978) and samples, discarding rocks over 20 mm in diameter, were taken for the following determinations:

1. pH - potentiometrically on all samples in a water-soil solution and also on selected samples using $CaCl_2$ (McMullan 1971).
2. Carbonate (presence) - on all samples using dilute HCl (Walmsley *et al.* 1979).
3. Texture - on selected samples using the hydrometer method (McKeague 1976).
4. Rock - for all samples, percentage by weight of particles 2 - 20 mm in diameter.

Plant cover was estimated by species. Nomenclature follows Taylor and MacBryde (1977) for vascular plants and Schofield (1968) for mosses.

RESULTS

I. The Vunder Fire

A. General Description

The Vunder Fire was started August 24, 1961, by lightning. The Duff Moisture Code (DMC)

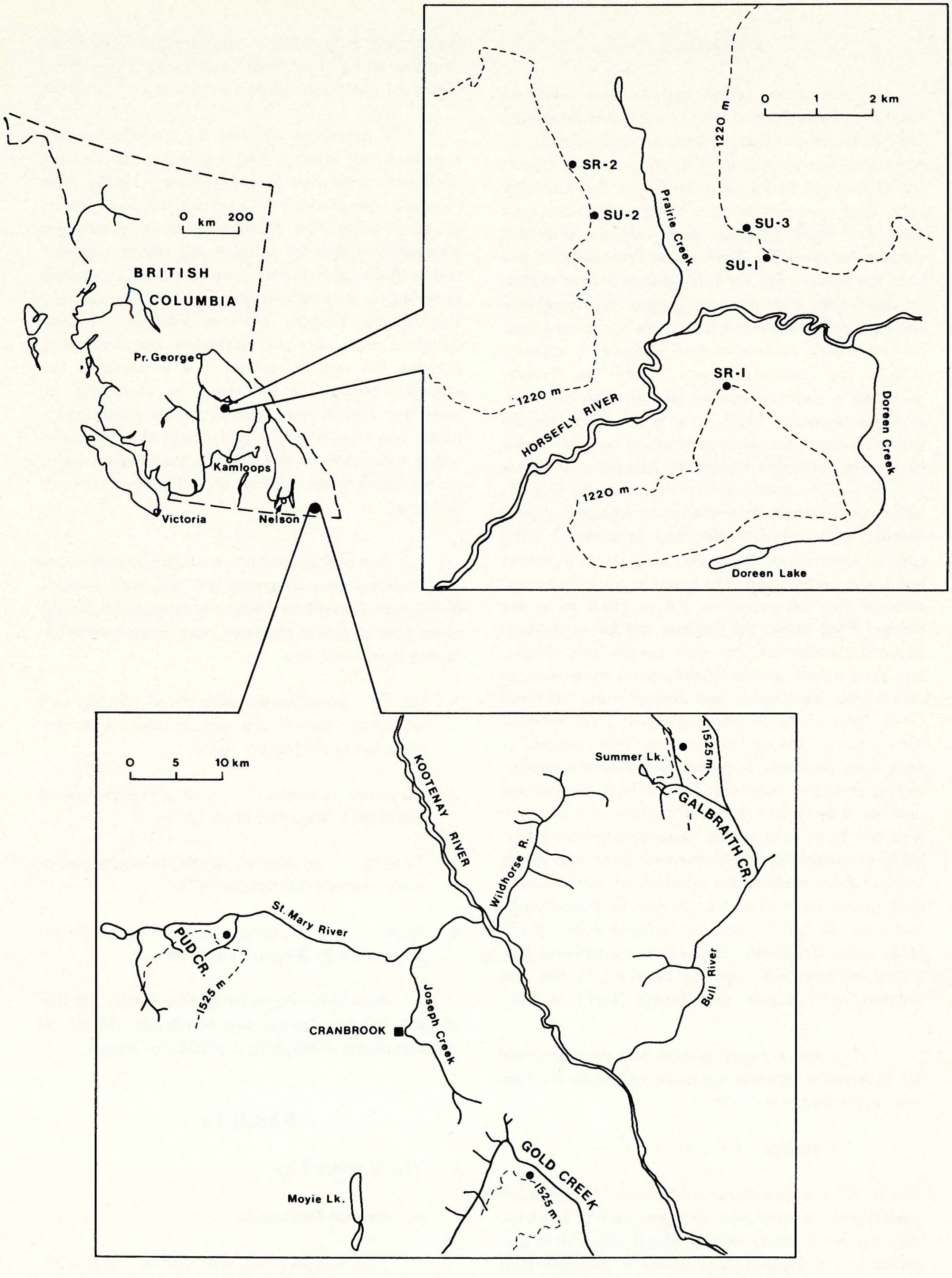

Fig. 2. Map of southeastern British Columbia showing locations of studies. Enlargements give locations of the five study areas on the Vunder Fire and the single areas on the Gold, Pud and Galbraith Fires.

on this date was 93, about three times the normal and the Drought Code (DC) was 556, about 250 points higher than the 10-year normal for the same period[2]. The burn was rapid, covering over 4,000 ha in the first 9 hours. The final size was about 10,100 ha. The time of burn coincided with an abundant seed crop on Douglas-fir and Engelmann spruce[3]. Seeds held in cones not consumed by the fire were apparently disseminated thickly over much of the burn. During the first winter, seeds were observed blowing along the crusted snow in great quantities[4]. The result has been a dense stocking of Douglas-fir, Engelmann spruce and lodgepole pine.

During 1961 to 1963, extensive salvage operations were conducted, using ground skidding techniques. Roads and skidroads constructed during this period destroyed established seedlings and buried or removed seeds. This has resulted, even to the present, in a pattern of understocked haul roads and skidroads with intervening overstocked sections. Sufficient fill-in has occurred on some of the skidroads to allow the present studies.

The Vunder Fire lies in the Quesnel Highlands physiographic region (Holland 1976). Bedrock exposures below about 1,200 m elevation are rare, the slopes being covered by a generally deep morainal material, often overlain by colluvium. Bedrock is mainly volcanic (*e.g.,* andesitic tuff) or sedimentary (*e.g.,* argillite and greywacke) (Campbell 1963). Soils are mainly Orthic Dystric Brunisols on the moderately coarse and coarse parent materials and Brunisolic Gray Luvisols on medium textures, with intergrades between the two. Precipitation is about 1,000 mm annually (Schwab and Watt 1980). Pedologic, topographic and vegetational details are included in Appendix 1A.

Annas and Coupé (1979) placed the study areas in the Interior Western Hemlock Wet Subzone. However, with western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) rarely occurring as regeneration, their drier Cedar Subzone seems a more appropriate category. At the upper limits, *i.e.,* over 1,200 m, the study areas abut the Engelmann Spruce - Subalpine Fir Zone. The forest ecosystem types most closely resemble the *Paxistima myrsinites* - *Pleurozium schrebiri* Association on mesic habitats and the *Cornus canadensis* - *Pleurozium schrebiri* Association on finer, slightly moister soils, as described for the Interior Western Hemlock Dry Subzone (Bell 1965).

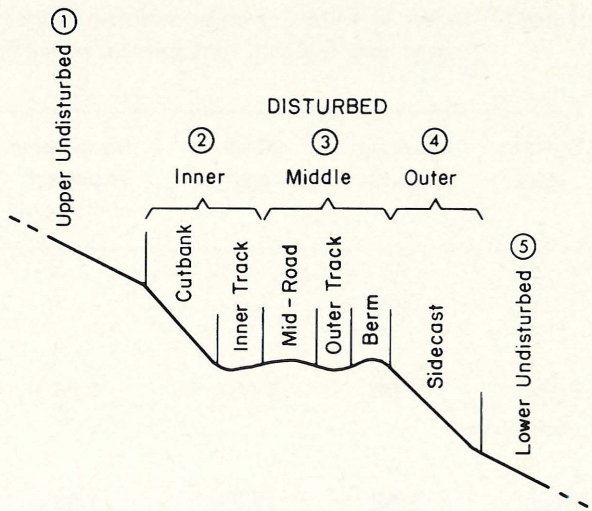

Fig. 3. Diagram of skidroad profile showing surface classes.

B. Tree Growth on Skidroad Surfaces

Two areas were found suitable for tree growth / skidroad surface studies.

Area SR - 1

In Area SR - 1, 22 skidroad segments were located and 110 Engelmann spruce and 109 Douglas-fir trees were sampled.

An average delay in stocking of about 3

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2 DMC and DC are defined by Van Wagner (1974). Actual values are derived from the nearest weather station, courtesy of B.D. Lawson, Pacific Forest Research Centre, Victoria, B.C.

3 In the Vunder Fire study area, Engelmann spruce has probably undergone some degree of hybridization with white spruce (*Picea glauca* [Moench] Voss). However, it will be referred to simply as Engelmann spruce in the text.

4 Personal Communication with O.J. Anderson, Jacobson Bros. Forest Products, Williams Lake, B.C.

Table 1. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights, and estimated height-growth enhancement or reduction for Douglas-fir, Area SR - 1, Vunder Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 11 yrs	Enhancement (+) or reduction (–) Specific	Enhancement (+) or reduction (–) Prorated[2]
	---m---	---yrs---		---cm---	%	%
Upper undisturbed	10.00	14.8 a	1.88 a	104.7	NA	NA
Inner disturbed	3.52	11.3 b	1.53 c	43.9	–56.9	–6.9
Middle disturbed	2.64	11.6 b	1.61 bc	53.0	–47.9	–4.3
Outer disturbed	3.29	11.4 b	1.73 b	72.3	–29.0	–3.3
Lower undisturbed	10.00	14.5 a	1.85 a	99.0	NA	NA
						–14.5

1 Means not followed by a common letter are significantly (p = 0.05) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable.

years on skidroad surfaces for Douglas-fir and Engelmann spruce was indicated by the differences in average sample-tree ages (Tables 1, 2).

Growth rates for Douglas-fir were significantly higher on both undisturbed surfaces than on all three disturbed surfaces (Table 1). Additionally, the growth rate on the outer disturbed surface was significantly greater than on the inner disturbed surface. As older trees on the disturbed surfaces became sparse, specific growth comparisons were made at age 11. Assuming that undisturbed surfaces supported normal growth and prorating enhancements and reductions over the whole clearcut, a reduction in growth capacity of 14.5% was estimated for Douglas-fir (Table 1). This reduction may be conservative, in that Douglas-fir growing in the overstocked, undisturbed portions may have suffered from competition.

Growth rates for Engelmann spruce were significantly lower on the inner disturbed surface than on the lower undisturbed, middle and outer disturbed surfaces (Table 2). At 11 years of age, the specific reduction on the inner disturbed, when compared with the lower undisturbed, was 34.8%. When prorated over the whole clearcut, this reduction was estimated as 2.1%.

Area SR - 2

Twenty-five skidroad segments were located and 119 Douglas-fir trees were sampled. No other

Table 2. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for Engelmann spruce, Area SR - 1, Vunder Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 11 yrs	Enhancement (+) or reduction (—) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	%
Upper undisturbed	10.00	14.6 a	1.54 ab	44.4	NA	NA
Inner disturbed	3.52	12.0 b	1.47 bc	37.9	–34.8	–2.1[3]
Middle disturbed	2.64	11.8 b	1.67 a	62.3	NS	NA
Outer disturbed	3.29	11.2 b	1.69 a	65.6	NS	NA
Lower undisturbed	10.00	14.5 a	1.64 a	58.1	NA	NA
						–2.1

1 Means not followed by a common letter are significantly ($p = 0.05$) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable; NS = Non-significant.

3 Significantly different only from lower undisturbed; therefore, prorated reduction divided by two.

species was present in sufficient numbers to allow adequate sampling.

Ages of sample trees from the undisturbed surfaces averaged 1 to 2 years older than those sampled from the skidroad surfaces (Table 3).

Growth rates for Douglas-fir were significantly higher on both undisturbed surfaces than on all three skidroad surfaces (Table 3). As older trees on the skidroad surfaces were sparse, specific growth comparisons were made at age 13. With the same assumptions noted previously, a prorated growth reduction of 13.5% was estimated.

C. Tree Growth on Skidded and Unskidded Slopes

The Vunder Fire provided three situations in which contour skidroads ended abruptly for reasons other than that of a terrain change. The slopes beyond the ends of the skidroads were subject to the same burn but were free from skidroads.

Area SU - 1

At this location, five skidroads ended abruptly (Fig. 4A). On either side of a 30-m buffer

Table 3. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for Douglas-fir, Area SR - 2, Vunder Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 13 yrs	Enhancement (+) or reduction (–) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	%
Upper undisturbed	10.00	15.6 a	1.90 a	147.6	NA	NA
Inner disturbed	2.21	13.4 b	1.60 b	66.6	–53.4	–5.4
Middle disturbed	2.60	14.2 b	1.69 b	85.7	–40.1	–4.8
Outer disturbed	2.20	14.1 b	1.73 b	96.0	–32.9	–3.3
Lower undisturbed	10.00	15.3 a	1.87 a	138.3	NA	NA
						–13.5

1 Means not followed by a common letter are significantly ($p = 0.05$) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable.

strip, ten 4.7 m^2 - plots were established in the main skidded and ten in the main unskidded portions. An additional five plots each were established immediately above the main skidded and unskidded portions.

The tallest lodgepole pine per plot was significantly shorter (22.5% reduction) in the skidded than in the unskidded section (Table 4). Similarly, the tallest Douglas-fir tree in the skidded portion was significantly shorter (19.5% reduction) than in the unskidded portion. No significant differences in height occurred between the two upper sections for either species. The stand was extremely dense, with the skidded portion containing the most trees per ha (Table 4).

Area SU - 2

Five skidroads with abrupt endings were studied as in Area SU - 1, but with additional central buffers to account for uneven skidroad endings (Fig. 4B). Twelve plots were established in each of the main skidded and unskidded areas and an additional five and seven plots above the skidded and unskidded portions, respectively. Plots were 3.0 – m (28.3 m^2) or 4.0 – m radius (50.3 m^2), depending on stand density.

There were no significant differences in the height of the tallest tree per plot for Douglas-fir or Engelmann spruce between skidded and unskidded

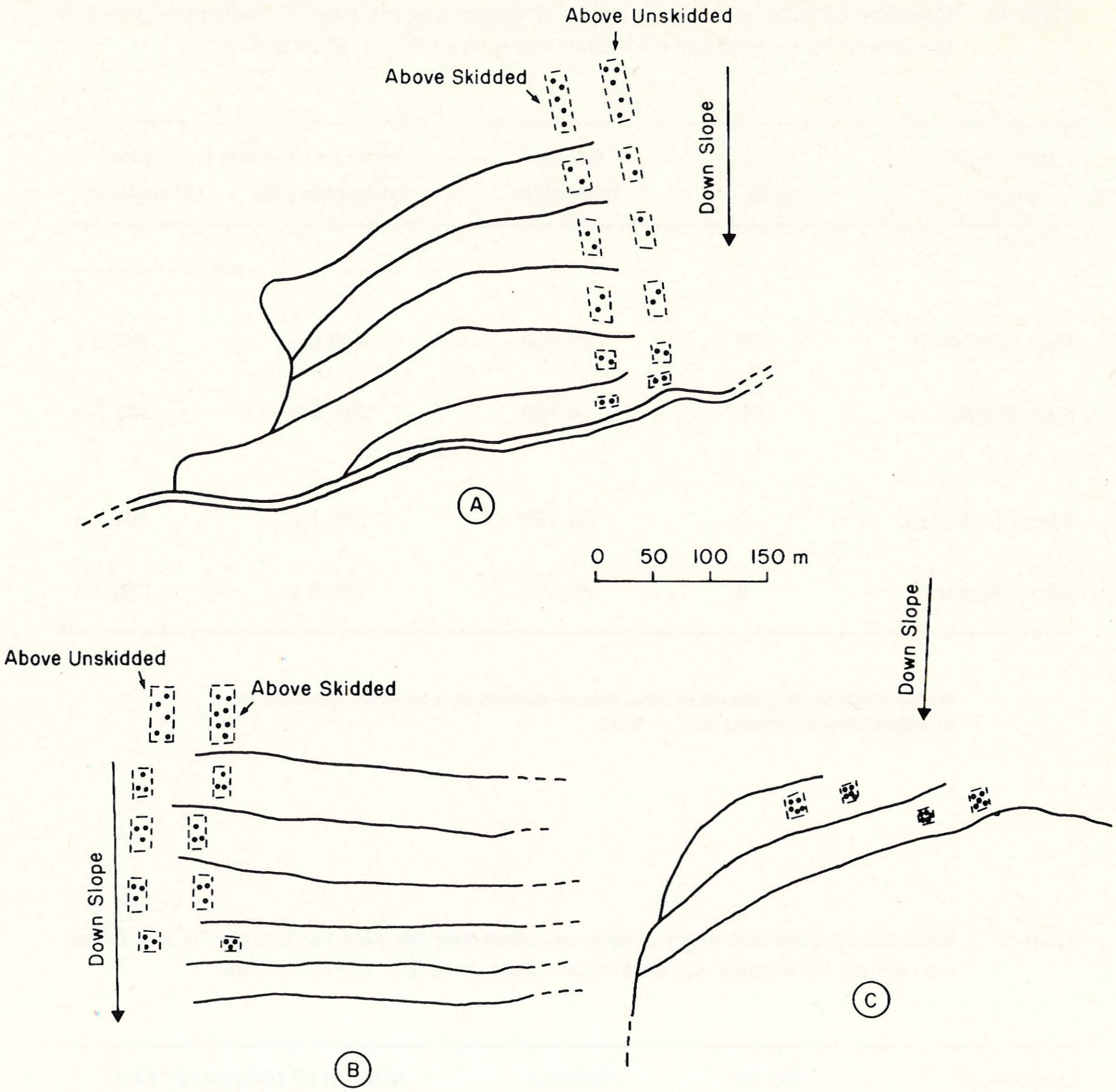

Fig. 4. Diagrams of skidroads and sample plots at skidded versus unskidded study areas in the Vunder Fire: A = Area SU-1; B = Area SU-2; C = Area SU-3.

portions nor above the skidded and unskidded portions (Table 5).

Area SU - 3

Sampling in this case was less elaborate than for the first two. Five 2.0 – m (12.6 m^2)– or 3.0 – m (28.3 m^2)– radius circular plots were established in a skidded and five in an unskidded portion associated with each of two single skidroads (Fig. 4C). The stand was almost pure lodgepole pine. No significant differences were found in growth rates of lodgepole pine between skidded and unskidded areas in either subarea when based on tallest tree per plot (Table 6).

II The Gold Fire

A. General Description

The Gold Fire was started on July 19, 1960, by lightning. At the time, the DMC was about 162, over twice the normal, and the DC was 526, about 160 points higher than the 10-year normal. The fire

Table 4. Densities of trees and mean heights of tallest tree per plot for lodgepole pine and Douglas-fir for skidded and unskidded slopes, Area SU - 1, Vunder Fire.

Location of plots	No. of plots	Density (stems/ha)	Mean ht of tallest tree / plot[1]	
			Lodgepole pine	Douglas-fir
			---------- cm ----------	
Main unskidded	10	83,360	446.6 a	282.9 a
Main skidded	10	114,760	345.9 b	227.7 b
Above unskidded	5	55,150	286.3 a	191.1 a
Above skidded	5	72,540	292.6 a	236.1 a

[1] Within tree species and pairs of data, means followed by a common letter are not significantly different at $p < 0.05$.

Table 5. Densities of trees and mean heights of tallest tree per plot for Douglas-fir and Engelman spruce for skidded and unskidded slopes, Area SU - 2, Vunder Fire.

Location of plots	No. of plots	Density (stems/ha)	Mean ht of tallest tree / plot[1]	
			Douglas-fir	Engelmann spruce
			---------- cm ----------	
Main unskidded	12	2,387	408.5 a	178.7 a
Main skidded	12	2,048	378.1 a	174.0 a
Above unskidded	7	625	244.5 a	167.8 a
Above skidded	5	654	325.7 a	169.1 a

[1] Within tree species and pairs of data, means followed by a common letter are not significantly different at $p < 0.05$.

Table 6. Densities of trees and mean heights of tallest tree per plot for lodgepole pine for skidded and unskidded slopes, Area SU - 3, Vunder Fire.

Location of plots	No. of plots	Density (stems/ha)	Mean ht of tallest tree / plot[1] Lodgepole pine
			---------------------- cm ----------------------
Subarea 1			
Unskidded	5	2,264	473.8 a
Skidded	5	2,547	435.4 a
Subarea 2			
Unskidded	5	15,756	505.2 a
Skidded	5	7,799	496.6 a

[1] Within pairs of data, means followed by a common letter are not significantly different at $p < 0.05$.

proved difficult to control because of heavy winds and the extremely dry conditions. When finally extinguished in late August, it had burnt over some 3,724 ha.

The Gold Fire lies in the southeastern extremities of the Purcell Mountain Range. Bedrock is Precambrian grey and green argillite and siltstone, grey quartzite, buff and orange-weathering dolomite and conglomerate (Leech 1960). Soils are Orthic Gray Luvisols, with intermittent free carbonates at depth (Appendix 1B). Precipitation is about 600 mm annually.

Utzig *et al.* (1978) placed the study area in the Dry Biogeoclimatic Region of the Nelson Forest Region. The flora in the area most closely resembles that characterizing the Dry Subzone of the Interior Douglas-fir Zone. The study area is essentially mesic with respect to soil moisture, with the most dominant forest association being *Arctostaphylos-Calamagrostis* (Kinnikinnick-Pinegrass) (Utzig *et al.* 1978).

B. Tree Growth on Skidroad Surfaces

Two species, western larch (105 trees) and Douglas-fir (88 trees), were sampled. The average larch and Douglas-fir sample-tree ages on all road surfaces were significantly less (2 - 3 years) than on the undisturbed surfaces (Table 7, 8). There were no significant differences in the age of sample trees between the two undisturbed surfaces for either species.

The growth rate of larch was significantly slower on the inner disturbed surface than on all other surfaces (Table 7). Growth rates among the latter four surfaces were not significantly different. Older trees were sparse on disturbed surfaces, so specific growth comparisons were made at age 13. At this age, height growth of larch on the inner track was 35.7% less than the average growth rate of larch on the undisturbed surface. Prorated over the whole clearcut, the reduction was estimated as 3.6%.

Growth rates for Douglas-fir were much slower than for western larch. The best growth was on the middle disturbed surfaces and this was significantly greater than that on the upper undisturbed or the inner disturbed surfaces (Table 8). Taken at age 13, the specific growth enhancement on the middle disturbed surface amounted to 58.6% when

Table 7. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for western larch, Gold Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 13 yrs	Enhancement (+) or reduction (—) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	
Upper undisturbed	7.50	16.2 a	2.17 a	313.1	NA	NA
Inner disturbed	2.13	13.2 c	2.02 b	206.4	–35.7	–3.6
Middle disturbed	2.92	13.4 c	2.27 a	394.7	NS	NA
Outer disturbed	1.81	14.6 b	2.21 a	340.0	NS	NA
Lower undisturbed	7.50	16.3 a	2.20 a	328.6	NA	NA
						–3.6

[1] Means not followed by a common letter are significantly (p = 0.05) different.

[2] Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable; NS = Non-significant.

compared with growth on the upper undisturbed surface. The prorated growth enhancement was estimated at 3.8%.

III The Pud Fire

A. General Description

The Pud Fire was ignited on July 12, 1960, during a lightning storm. On this date, the DMC of 119 was over 60% higher than normal and the DC of 462 was about 130 points above the 10-year normal. The fire burnt over 4,200 ha before being completely extinguished in September.

The burn lies in the eastern edge of the Purcell Mountain Range west of Marysville. Bedrock is mainly rusty weathering quartzite, siltstone and argillite and metamorphosed equivalents, with some intrusive diorites and quartz diorites (Leech 1957, 1960). Soils are coarser than in the Gold Fire study area and are generally Orthic or Eluviated Dystric Brunisols (Appendix 1C). Precipitation is about 700 mm annually. As with the Gold Fire, the study area lies in the Dry Biogeoclimatic Region, Interior Douglas-fir Zone, Dry Douglas-fir Subzone (Utzig *et al.* 1978) but with some tendency toward the Moist Southern Interior Cedar-Hemlock Subzone[5]. The forest ecosystem type is mainly mesic *Arctostaphylos - Calamagrostis.*

[5] Personal communication with D. Macdonald, B.C. Forest Service, Nelson Forest Region, Nelson, B.C.

Table 8. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for Douglas-fir, Gold Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 13 yrs	Enhancement (+) or reduction (—) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	%
Upper undisturbed	7.50	16.5 a	1.77 b	106.8	NA	NA
Inner disturbed	2.23	13.7 b	1.73 b	95.6	NS	NA
Middle disturbed	2.89	14.1 b	1.95 a	169.4	+ 58.6	+ 3.8[3]
Outer disturbed	2.02	13.2 b	1.94 ab	167.5	NS	NA
Lower undisturbed	7.50	15.9 a	1.83 ab	125.7	NA	NA
						+ 3.8

1 Means not followed by a common letter are significantly (p = 0.05) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable; NS = Non-significant.

3 Significantly different only from upper undisturbed; therefore, prorated enhancement divided by two.

B. Tree Growth on Skidroad Surfaces

The stand was almost pure lodgepole pine and thus only that species was sampled. Based on 89 sample trees, those on the undisturbed surfaces were 1 - 2 years older than trees from the middle disturbed section (Table 9). The age of trees on the lower undisturbed was also greater than that of trees on the inner and outer disturbed surfaces.

There were no significant differences in growth rates among surface classes (Table 9), though there was a tendency for better growth on the middle disturbed surface. Because of the lack of significant growth differences, no growth reduction or enhancements could be attributed to the skidroad surfaces.

IV The Galbraith Fire

A. General Description

The Galbraith Fire was started on July 13, 1960, by lightning and burned 4,225 ha before being extinguished in late August. Both the DMC and DC were abnormally high, as detailed for the Pud Fire which was ignited the previous day.

The area lies in the Rocky Mountain (Kootenay) Physiographic Region (Holland 1976). The bedrock is Paleozoic limestone and shale (Leech 1960). In the study area, loose limestone rocks are abundant and the soils are calcareous Orthic Eutric Brunisols (Appendix 1D). Precipitation is about

Table 9. Skidroad widths, average sample-tree ages and curve-generated heights for lodgepole pine, Pud Fire.[1]

Surface class	Average width	Mean age[2]	Mean curve regression coefficient[2]	Height from curve at 14 yrs
	---m---	---yrs---		---cm---
Upper undisturbed	7.50	15.3 ab	2.28 a	484.6
Inner disturbed	3.09	14.5 bc	2.27 a	461.3
Middle disturbed	2.71	13.9 c	2.36 a	591.9
Outer disturbed	3.13	14.7 bc	2.30 a	512.3
Lower undisturbed	7.50	16.0 a	2.29 a	496.1

1 Because there are no significant differences between the height-growth rates of disturbed and undisturbed classes, no growth enhancements or reductions are shown.

2 Means not followed by a common letter are significantly ($p = 0.05$) different.

1,000 mm annually. The study area appears to be in a transition zone between the Dry and Moist Biogeoclimatic Regions and between the Interior Douglas-fir and Engelmann Spruce - Subalpine Fir Zones (Utzig *et al.* 1978).

Because of its transitional nature, the area is difficult to characterize by forest ecosystem type, though it tends to be similar to the *Ribes lacustre - Veratrum viride* type of the Engelmann Spruce - Subalpine Fir Zone. Many of the plants listed for this association (Utzig *et al.* 1978) are not found in the study area, but some that are present, such *Thalictrum occidentale, Viola glabella, Sorbus sitchensis* and *Ribes lacustre,* are indicative of a moister and cooler climate than usually associated with the Douglas-fir Zone.

B. Tree Growth on Skidroad Surfaces

Douglas-fir and Engelmann spruce sample trees on the undisturbed surfaces were 3 - 5 years older than on all the disturbed surfaces (Tables 10, 11). There were no significant differences in the ages of trees on the upper and lower undisturbed nor among the disturbed surface classes.

The growth rate of Douglas-fir was significantly higher on the undisturbed surfaces than on the inner and middle disturbed surfaces (Table 10). Growth on the outer disturbed class was also significantly greater than on the inner and middle disturbed classes. Prorated reductions in height growth at age 11 years amounted to 12.0%.

Table 10. Skidroad widths, average sample-tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for Douglas-fir, Galbraith Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 11 yrs	Enhancement (+) or reduction (—) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	
Upper undisturbed	7.50	14.1 a	1.79 a	84.0	NA	NA
Inner disturbed	3.34	10.9 b	1.46 b	37.0	–56.6	–4.9
Middle disturbed	5.29	10.9 b	1.51 b	41.4	–51.5	–7.1
Outer disturbed	3.73	10.9 b	1.69 a	66.1	NS	NA
Lower undisturbed	7.50	14.6 a	1.79 a	86.6	NA	NA
						–12.0

1 Means not followed by a common letter are significantly (p = 0.05) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable; NS = Non-significant.

The growth rate of Engelmann spruce was significantly less on the inner disturbed surface than on the upper and lower undisturbed surfaces (Table 11). No other significant differences in growth occurred. Specific reductions, calculated at 10 years of age, amounted to 34.4% for the inner disturbed. The prorated reduction was estimated at 3.0%.

V. Relative Growth Response with Time

The mathematically produced height-growth curves do not allow examination of changes in relative growth rates with time; *i.e.,* whether the height position of trees growing on a particular surface changes in time in relation to the other surfaces. Examination of the original height-growth data and performance of multiple range tests indicated two study areas in which growth rates changed differentially with time. In the Gold Fire, Douglas-fir growing on the middle disturbed surface was significantly taller than that on the upper undisturbed and inner disturbed surfaces at 8 years of age. By 13 years, the average height of trees in both the middle and outer disturbed surfaces was significantly greater than on each of the inner disturbed and upper and lower undisturbed surfaces. In the same area, western larch height at 10 years on the inner disturbed surface was significantly less than on all other surfaces, but at 13 years was only significantly less than on the middle disturbed surface. Additionally, the heights on the latter surface at 13 years were significantly greater than on the two undisturbed surfaces. Finally, the height of Engelmann spruce at the Galbraith Fire at

Table 11. Skidroad widths, average sample tree ages, regression coefficients, curve-generated heights and estimated height-growth enhancement or reduction for Engelmann spruce, Galbraith Fire.

Surface class	Average width	Mean age[1]	Mean curve regression coefficient[1]	Height from curve at 10 yrs	Enhancement (+) or reduction (–) Specific	Prorated[2]
	---m---	---yrs---		---cm---	%	%
Upper undisturbed	7.50	14.7 a	1.69 a	54.1	NA	NA
Inner disturbed	3.34	10.7 b	1.47 b	34.4	–34.4	–3.0
Middle disturbed	5.29	11.1 b	1.57 ab	42.1	NS	NA
Outer disturbed	3.73	10.1 b	1.61 ab	46.3	NS	NA
Lower undisturbed	7.50	14.5 a	1.64 a	50.6	NA	NA
						–3.0

1 Means not followed by a common letter are significantly ($p = 0.05$) different.

2 Prorated on the basis of a 32.3% coverage of skidroads and on the measured average widths of the skidroad disturbance classes. NA = Not applicable; NS = Non-significant.

7 years was significantly less on the inner disturbed surface than on the upper undisturbed surface, but no differences were noted when heights at 10 years were tested.

VI. Color of Foliage

The hue of Douglas-fir foliage was somewhat yellower when growing on the inside of the skidroad in the Vunder Fire, Area SR - 1, generally yellower on the skidroads in the Gold Fire and yellower on the outside disturbed surface in the Galbraith Burn when compared with foliage of trees growing on undisturbed surfaces in these locations. Engelmann spruce foliage was yellower on road surfaces in the Vunder Burn, Area SR - 1, than on undisturbed surfaces. Otherwise, there were no marked differences in hue. Value (degree of lightness or darkness) showed no particular pattern but, for several study areas, chroma (strength) tended to be lower for trees on the skidroad surfaces than on the undisturbed.

DISCUSSION AND CONCLUSIONS

Salvaged wildfire areas proved to be useful for ascertaining the influence of soil disturbance by skidroad construction on tree growth. The absence of advance regeneration eliminated the problem of competition from that source and generally allowed more efficient sampling than in unburned clearcuts. However, generally higher tree densities between skidroads than on them may have favored tree growth on the skidroad surfaces.

Extreme fire weather and fuel moisture indices at the time of all burns and the absence of living residual trees suggest that all fires were intense and that productivity on the otherwise undisturbed surfaces may have been affected. Since no evidence exists that such effects differed in degree among the four locations, fire intensity has not been considered in reaching the conclusions which follow.

As with the unburned clearcuts studied previously (Smith and Wass 1979), tree growth rates reflected the change in soil conditions from the inner gouge to the outer, mixed deposit. In all of the eight tree species/area combinations studied, height growth was slowest on the inner skidroad surface. In five of the eight cases, growth rates increased outward through the middle disturbed into the outer disturbed surface. In three, the greatest growth rate was in the middle, but not by a statistically significant margin over the outer disturbed surface. The actual deviation of growth rates from that found on undisturbed surfaces is a more complicated question involving a wide range of biogeoclimatic parameters. The most marked reductions in height growth on skidroad surfaces were found for Douglas-fir at the Vunder Fire study area located in the climatically wet Western Hemlock Zone, and in the calcareous soils of the Galbraith Fire. The latter result agrees with known general effects of calcareous soils on tree growth (Utzig and Herring 1974) and with the results of specific studies involving Engelmann spruce and subalpine fir (Smith and Wass 1979). The marked adverse effects at the Vunder Fire are likely associated with the coarse nature of the soils and the lack of available nutrients once surface horizons are eliminated or diluted with subsoil material. In direct contrast, growth rates on skidroads were virtually unaffected in the Pud and Gold Fires situated in the Douglas-fir Zone. These sites were characterized by the grass, *Calamagrostis rubescens,* and by mesotrophic, moderately coarse to medium textured soil. Soils in this relatively dry zone would be expected to have a more favorable nutrient status at depth than those more podzolized ones in wetter zones.

Combining the results of this study with the earlier one (Smith and Wass 1979) and utilizing pertinent findings reported in the literature, a rating system was devised to allow an assessment of the potential effect of skidroad disturbance on the growth rates of trees growing on the disturbed surfaces (Table 12). The basic scheme does not account for some unusual enhancement of growth in two high-elevation, north-facing (356^{o} and 025^{o}) sites at Templeton Creek and one south-facing (192^{o}) area at Batys Creek. In the first instance, removal of organic horizons probably gave trees growing on mineral soil surfaces an advantage in terms of higher growing season soil temperatures (Anderson 1955; Dobbs and McMinn 1973). Also, insolation on north-facing slopes increases as the ground surface approaches 0% inclination (Geiger 1957). In the case of the hot south-facing slope, reduced soil temperatures on the flat skidroad surface compared with the sloping, undisturbed surface (Geiger 1957) would be an advantage. We have thus instituted a 2-point deduction for steep slopes (over 45%) which face north (325^{o} - 045^{o}) or south (135^{o} - 225^{o}). Calcareous soils outweigh the aspect effects and are not under any circumstances subjected to a 2-point deduction. Burned, north-facing slopes are not subject to a deduction as, presumably, the insulating properties of the humus are already reduced appreciably by burning (Hermann 1963). None of these aspect effects are well substantiated and are subject to revision as additional information is gained.

Referring to the rating system (Table 12), the most adverse effect on growth would result from disturbance of a calcareous, shallow or coarse textured soil in a wet biogeoclimatic region - a maximum point total of 12. None of the areas studied were in this category. The Galbraith Fire with 10 and Shuswap, Albert and Inlet Creeks with 9 points were closest (Table 13). Russell Creek and Vunder Fire (SR - 1) received the highest point total possible of 9 for acid soils. At the opposite end of the scale, the Pud and Gold Fires were rated 3 (Table 13). Low ratings also accrued to the Templeton Creek sites which produced enhanced tree growth on the skidroad surfaces (Table 13).

As to what should be considered a problem site, we can make some general suggestions. Sites with ratings of 7 or more can be expected to experience a prorated loss in height growth of about 5 - 15%, based on 32% coverage of skidroad surfaces. This amount would be increased or decreased proportionally with increasing or decreasing skidroad density. Those sites with a rating less than 7 may suffer small growth losses or, in special cases, an enhancement of growth of up to 20%. So few of the latter cases were sampled that we could not develop a rating system that would consistently separate them out. Sites with ratings of less than 7 will have to be

Table 12. Rating scheme for assessing sites for growth response of trees growing on skidroad surfaces.

Factor		Degree	Points	Characteristics[1]
1. SOIL ACIDITY	a)	Calcareous: free carbonates within 1 m of surface; pH 7.0 - 8.5; usually Eutric Brunisols, Regosols and Gray Luvisols.	6	Very low availability of elements such as P, Fe, Zn, B and Mn (Thorne 1955; Lutz and Chandler 1946).
	b)	Acid: pH of C horizon less than 5.6 (measured in $CaCl_2$); usually Podzols and Dystric Brunisols.	3	Low rate of microbiological tranformations (Thorne 1955); low N availability, low cation availability (Pritchett 1979).
	c)	Neutral: non-calcareous in upper 1 m and pH of C horizon 5.6 or greater; usually Eutric Brunisols, Dystric Brunisols and Gray Luvisols.	1	Relatively favorable nutrient status and availability throughout profile.
2. SOIL TEXTURE and DEPTH	a)	Coarse: sands and loamy sands; and/or shallow: less than 1 m to bedrock.	3	Low cation exchange capacity in mineral soil; low soil volume; low moisture holding capacity in mineral soil; rapid leaching of nutrients.
	b)	Moderately fine to fine: sandy clay, clay, silty clay, clay loam, silty clay loam.	2	Restricted root growth through compaction by machinery and naturally compact horizons (Forristall and Gessel 1955; Pearce 1958; Dyrness 1965).
	c)	Medium to moderately coarse; sandy loam, loam, silt loam, silt, very fine sandy loam.	1	Relatively high cation exchange capacity in mineral soil; moderate to low compactibility.
3. CLIMATE	a)	Wet: Engelmann Spruce - Subalpine Fir Zone in Moist and Wet Biogeoclimatic Regions (Utzig *et al.* 1978) and all Western Hemlock Zone.	3	Rapid leaching of exposed mineral soils which are generally podzolized and of relatively low base status.
	b)	Moist: Engelmann Spruce - Subalpine Fir Zone in Dry Biogeoclimatic Regions and all Sub-boreal Spruce.	2	Moderately rapid leaching of exposed mineral soils which are weakly podzolized, Luvisols or Brunisols of moderate base status.
	c)	Dry: Interior Douglas-fir and Ponderosa Pine zones.	1	Slow leaching of exposed mineral soils which are Brunisolic to Chernozemic and provided with relatively high base status and more uniform organic carbon distribution.

[1] General notes on nutrient status of the various soils comes from Smith (1965) and Valentine, *et al.* (1978).

Table 13. Ratings for areas studied with their prorated reductions and enhancements[1].

Location	Ratings					Growth enhancement or reduction[2]				
	Acidity	Texture	Climate	Aspect deduction	Total	Engelmann spruce	Subalpine fir	Douglas-fir	Western larch	Lodgepole pine
Galbraith Fire	6	1	3	0	10	– 3.0	–	–12.0	–	–
Albert Creek	6	1	2	0	9	– 4.7	–	– 8.4	–	–
Inlet Creek	6	1	2	0	9	–12.1	–13.2	–	–	–
Shuswap Creek	6	1	2	0	9	–11.0	–14.8	–	–	–
Vunder Fire - SR - 1	3	3	3	0	9	– 2.1	–	–14.5	–	–
Russell Creek	3	3	3	0	9	+ 0.3	– 9.6	–	–	–
Vunder Fire - SR - 2	3	1	3	0	7	–	–	–13.5	–	–
Wildhorse Creek	1	1	3	0	5	+ 4.8	– 6.7	–	–	–
Batys Creek	3	1	3	2	5	+ 4.7	+13.1	–	–	–
Templeton Creek - 1	3	1	2	2	4	+21.9	+18.5	–	–	–
Templeton Creek - 2	3	1	2	2	4	+19.0	– 2.2	–	–	–
Gold Fire	1	1	1	0	3	–	–	+ 3.8	– 3.6	–
Pud Fire	1	1	1	0	3	–	–	–	–	0.0

1 Areas are those described in Smith and Wass (1979) and this study. Rating system is from Table 12.

2 Enhancements (+) and reductions (–) are prorated over the whole clearcut based on a 32.3% cover of skidroad surfaces.

considered simply as posing "no problems" in terms of the growth rate of trees growing on the disturbed surfaces.

Prior to mathematical manipulation, several height/age curves indicated improved growth potential of disturbed surfaces with time in relation to curves for adjacent undisturbed surfaces. Improving soil conditions might occur from, for instance, loosening of compact soils by frost and plant-root action. While the possibility of natural soil amelioration is acknowledged, increasing competition for growing space, expecially on the undisturbed surfaces, makes future trends difficult to project.

The foregoing discussion assumes that the growth of trees on the undisturbed surfaces is normal, albeit logged and sometimes burned, and can serve as the standard against which the growth of trees on the disturbed surfaces can be compared. What of the effects of the skidroads on trees growing below them by, for instance, interception of seepage water (Megahan 1972)? Unfortunately, the results from our salvage-logged, skidded versus unskidded studies were not conclusive. Although height growth was significantly slower in the skidded portion as compared with the unskidded portion in one area, no significant differences were found in two others, though trends were for better growth on the unskidded sites. Furthermore, the area that showed a growth impact had a greater stand density in the skidded than in the unskidded portion, which could have reduced growth disproportionately on the skidded side. The soil in this area was, however, medium textured with a strongly compact subsoil, and seepage water running along the compact layer could well be diverted by the road construction to the detriment of trees growing lower on the slope. Additional historical studies of the nature reported here would be extremely useful, but sites for such investigation are difficult to locate. Conclusive results may come only from long-term experimental studies, including pre- and post-road construction monitoring of moisture regimes and tree growth.

In addition to growth effects, a delay in stocking on skidroad surfaces is found in all areas. On salvage-logged burns, the delay is accentuated by the actual destruction of seeds and seedlings during the salvage logging operations.

SUMMARY AND RECOMMENDATIONS

It is clear that significant reductions in site productivity occur on some steeply sloping ecosystems when ground skidding is employed as the yarding method. On other ecosystems, effects appear minimal or even favorable to tree growth. By utilizing a rating system based on soil and climatic factors, the direction and general degree of response to disturbance can be estimated. Reductions of any adverse effects can result from shifting to cable systems (Wellburn 1975; Smith and Wass 1976), modifying ground skidding techniques, *e.g.,* small tractors (McMorland 1980), or timing, *e.g.,* yarding on snow (Smith and Wass 1976), or by ameliorating effects after yarding. Any ameliorative action requires a thorough knowlege of those soil factors most responsible for the tree-growth problem. Some differences in foliage color, for instance, suggest nutrient deficiences on portions of the skidroad. Soil compaction is a probable causitive factor, particularly in medium- to fine-textured soils and in soils that are compact at depth. To gain confidence in selecting an effective ameliorative procedure, detailed studies of soils underlying skidroad surfaces must be conducted to correlate specific physical and chemical soil characteristics with the varying tree-growth responses. Once sufficient information is available for planning necessary and effective ameliorative action, the costs of such action can be estimated and included in projections of total costs when comparing alternative harvesting systems and techniques.

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Fig. 5. Reconnoitering the 1960 Pud Fire, Marysville.

Appendix 1. Landform, soil and vegetation data for the four wildfire areas.

A. VUNDER FIRE

Subarea / Terrain / Soil	Major horizons[1]	pH[2] H_2O	pH[2] $CaCl_2$	Texture[1] < 2 mm	Vol rock[3] %	Wt gravel[4] %	Major non-tree plants
SR - 1. Deep, coarse colluvium	L						*Polytrichum juniperinum*
overlain by a moderately	FH	5.4 - 6.2					*Peltigera aphthosa*
coarse (erosional) deposit.	Bm	5.8 - 6.3	5.0 - 5.8	sl	23	49	*Peltigera canina*
	BC	5.0 - 6.2		ls	86	68	*Paxistima myrsinites*
Avg elevation - 1158 m	C(IIC)	5.9 - 6.4	5.2 - 5.9	ls	66	68	*Ribes lacustre*
Avg slope - 59%							*Rubus parviflorus*
Avg aspect - 340°							*Shepherdia canadensis*
Soil subgroup - Orthic							*Spiraea betulifolia*
Dystric Brunisol							*Vaccinium membranaceum*
							Clintonia uniflora
							Orthilia secunda
SR - 2. Deep, coarse to moderately	L						*Polytrichum juniperinum*
coarse colluvium over compact	FH	4.2 - 5.5					*Epilobium angustifolium*
moderately coarse to medium	Bm	5.9 - 6.4	5.2 - 5.7	sl	41	51	*Peltigera canina*
textured morainal deposit.	BC	6.0 - 6.3		ls - sl	62	61	*Paxistima myrsinites*
	C(IIC)	6.0 - 6.8	5.5 - 6.0	ls-l	54	53	*Ribes lacustre*
Avg elevation - 1086 m							*Rubus idaeus*
Avg slope - 52%							*Rubus parviflorus*
Avg aspect - 061°							*Clintonia uniflora*
Soil subgroup - Orthic							*Cornus canadensis*
Dystric Brunisol							*Pyrola asarifolia*
							Orthilia secunda

A. VUNDER FIRE (continued)

Subarea / Terrain / Soil	Major horizons[1]	pH[2] H_2O	pH[2] $CaCl_2$	Texture[1] < 2 mm	Vol rock[3] %	Wt gravel[4] %	Major non-tree plants
SU - 1. Deep, medium textured	L						*Rosa woodsii*
colluvium over compact,	FH	5.8 - 6.2					*Epilobium augustifolium*
mottled medium to fine	Bm(Bf)	5.6 - 6.0		l	15	29	*Linnaea borealis*
textured morainal deposit.	Ae	6.0 - 6.6		l	31	32	*Clintonia uniflora*
	Btg	6.2 - 7.2	6.1 - 6.5	l-cl	28	32	*Cornus canadensis*
Avg elevation - 1141 m							*Paxistima myrsinites*
Avg slope - 50%							*Rubus parviflorus*
Avg aspect - 206°							*Shepherdia canadensis*
Soil subgroup - Gleyed							*Spiraea betulifolia*
Brunisolic Gray							*Vaccinium membranaceum*
Luvisol							*Berberis aquifolium*
SU - 2. Deep, medium textured	L						*Taraxicum officinale*
colluvium over strongly	FH	6.2 - 6.3					*Ribes lacustre*
compact, medium textured	Bfj	5.5 - 5.6		l	15	57	*Paxistima myrsinites*
morainal deposit.	Bm	5.6 - 5.9	5.1	sl-l	17	60	*Arnica* sp.
	C	5.9 - 6.2	5.7 - 6.0	l	16	65	*Orthilia secunda*
Avg elevation - 1186 m							*Polytrichum juniperinum*
Avg slope - 50%							*Peltigera aphthosa*
Avg aspect - 094°							*Cladonia* sp.
Soil subgroup - Orthic							*Anaphalis margaritacea*
Dystric Brunisol							*Epilobium angustifolium*
							Aster sp.

A. VUNDER FIRE (continued)

Subarea / Terrain / Soil	Major horizons[1]	pH[2] H_2O	pH[2] $CaCl_2$	Texture[1] < 2 mm	Vol rock[3] %	Wt gravel[4] %	Major non-tree plants
SU - 3. Deep, coarse to		Unskidded					
moderately coarse textured	L						*Rosa woodsii*
colluvium over strongly	FH	5.9					*Penstemon fruticosus*
compact coarse textured	Bm	5.6 - 6.0	5.0	sl	50	44	var. *scouleri*
morainal deposit.	BC	5.8		sl	40	61	*Acer glabrum*
	C	6.2	5.9	ls	50	68	*Rubus idaeus*
Avg elevation - 1264 m	IIC	6.2 - 6.4	5.8	ls	54	64	*Paxistima myrsinites*
Avg slope - 69%							*Aster conspicuus*
Avg aspect - 176^o		Skidded					*Amelanchier alnifolia*
Soil subgroup (unskidded)	L						*Berberis aquifolium*
- Orthic Dystric Brunisol;	FH						*Shepherdia canadensis*
(skidded) -	Bm	6.4 - 7.0	6.5	sl	65	69	*Rubus parviflorus*
Orthic Eutric Brunisol	BC	6.8		ls	40	73	*Orthilia secunda*
	C	6.8 - 6.9	5.9	ls	31	64	*Spiraea betulifolia*
	IIC	6.8	6.3	sl	20	52	

B. GOLD FIRE

Subarea / Terrain / Soil	Major horizons	pH H_2O	pH $CaCl_2$	Texture < 2 mm	Vol rock %	Wt gravel %	Major non-tree plants
Deep, moderately coarse	L						*Calamagrostis rubescens*
to medium textured	FH	6.3 - 6.6					*Hedysarum sulphurescens*
morainal deposit; inter-	Ae	6.5		sl	16	33	*Polytrichum juniperinum*
mittently calcareous at	AB	6.2		sil	10	23	*Spiraea betulifolia*
70 cm +.	Bt	6.0 - 7.1	6.6 - 6.9	sl-l	32	43	*Vaccinium myrtillus*
Avg elevation - 1280 m							*Arnica* sp.
Avg slope - 42%							*Linnaea borealis*
Avg aspect - 094^o							*Rosa acicularis*
Soil subgroup - Orthic							*Amelanchier alnifolia*
Gray Luvisol							*Shepherdia canadensis*
							Ceanothus velutinus

C. PUD FIRE

Terrain / Soil	Major horizons[1]	pH[2] H$_2$0	pH[2] CaCl$_2$	Texture[1] < 2 mm	Vol rock[3] %	Wt gravel[4] %	Major non-tree plants
Moderately deep, moderately	L						*Calamagrostis rubescens*
coarse textured colluvium	FH	6.1					*Orthilia secunda*
over compact to strongly	(Aej)	6.2	5.1	sl	25	39	*Linnaea borealis*
compact moderately	Bm	5.8 - 6.1	5.4	sl	21	40	Spiraea *betulifolia*
coarse textured morainal	BC	6.0 - 6.4	5.9	sl	28	44	*Astragalus miser*
deposit with some	(IIBC)	6.6		ls	0	4	*Lonicera utahensis*
lens of stratified fluvium.	C	6.8	6.2	sl	30	52	*Rubus parviflorus*
Avg elevation - 1377 m							*Shepherdia canadensis*
Avg slope - 64%							*Vaccinium myrtillus*
Avg aspect - 118^o							*Polytrichum juniperinum*
Soil subgroup - Orthic							*Hedysarum sulphurescens*
Eutric to Dystric Brunisol							

D. GALBRAITH FIRE

Terrain / Soil	Major horizons[1]	pH[2] H$_2$0	pH[2] CaCl$_2$	Texture[1] < 2 mm	Vol rock[3] %	Wt gravel[4] %	Major non-tree plants
Moderately deep, medium	L						*Rubus parviflorus*
textured overlay on	FH	6.8					*Thalictrum occidentale*
medium textured	Bm	6.5 - 7.8		l-sil	10	23	*Aster conspicuus*
colluvium; calcareous	IIBmk	7.8		sil	40	49	*Epilobium angustifolium*
at 15-56 cm +	IIIBCk	8.2		l	20	43	*Amelanchier alnifolia*
below surface.	IVCk	8.2	7.4	l	40	51	*Paxistima myrsinites*
Avg elevation - 1580 m							*Ribes lacustre*
Avg slope - 50%							*Ribes viscosissimum*
Avg aspect - 239^o							*Sorbus sitchensis*
Soil subgroup - Orthic							*Elymus hirsutus*
Eutric Brunisol							*Viola glabella*
							Smilacina racemosa
							Bromus vulgaris

1 Terminology as in Canada Soil Survey Committee, Subcommittee on Soil Classification (1978).
2 H$_2$0 = pH taken in soil-water paste; CaCl$_2$ = pH taken in 0.01 M CaCl$_2$ solution.
3 Volume of rock over ca 2 cm estimated from pit face.
4 Weight of gravel (2 — 20 mm) expressed as percentage of collected sample.

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