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Contents

Feasibility of harvesting timber from small canopy openings in wetbelt Douglas-fir stands

Abstract

In 1997, the Cariboo Forest Region of the British Columbia Ministry of Forests, in co-operation with the Williams Lake Division of Weldwood of Canada Limited, carried out a study to examine how harvesting trees from several small openings within a block affects mule deer winter habitat. The Forest Engineering Research Institute of Canada (FERIC) monitored the harvesting component of the project, and compared the productivities and costs of working in canopy openings of different sizes.

Keywords

Harvesting, Environmental aspects, Canopy openings, Douglas fir, Wildlife habitat, Male deer, Productivity, Costs, British Columbia.

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Introduction

In 1997, the Cariboo Forest Region of the British Columbia Ministry of Forests (BCMOF), in co-operation with the Williams Lake Division of Weldwood of Canada Limited and the Cariboo Regional Office of the British Columbia Ministry of Environment (BCMOE) at Williams Lake, carried out a study to examine the effects of harvesting trees from small openings within a block on mule deer winter habitat in the Central Interior of B.C.

In co-operation with Weldwood and its contractor, Lamar Ventures Ltd., FERIC monitored the harvesting component of the project.[1] This report documents and compares the harvesting productivities and costs, examines the contractor's operating practices, and discusses the feasibility of operating in different opening sizes.

Mule deer prefer to spend the winter in range areas with the following attributes: aspects of SE, S, SW or W; slopes of 10–45%; elevations below 1500 m in moderate snowpack zones and below 1000 m in deep snowpack zones; and stands of predominantly Douglas-fir (*Pseudotsuga menziesii*) (Armleder et al. 1986). The chance of deer surviving through winter depends on their physical condition before the winter, and the availability of both good winter range and good spring range.

Recently, in the Cariboo Forest Region, clearcutting followed by artificial regeneration has been the silvicultural system used in the mule deer winter range. However, a group selection system with canopy openings appropriately located and oriented within the stand may better meet cover, forage, and movement requirements of wintering mule deer while ensuring regeneration of Douglas-fir. While the original stand attributes are usually not retained by clearcutting and shelterwood systems, they are retained when harvesting small openings (BCMOF 1998).

[1] Two more cutting entries are planned, with the second one to occur within 50 years of the first harvest. However, specific timing of the second and third entries is under discussion as the BCMOF and BCMOE prepare a mule deer winter range plan.

When canopy openings are no wider than two tree heights, snow depths are minimized. Also, Douglas-fir seedlings have low resistance to frost, but small openings maintain enough cover to provide some frost protection while still ensuring that adequate levels of light reach into the opening.

As with any partial cutting system, the windthrow risk must be determined and managed. Openings need to be oriented and sized so that the negative influences of wind on the residual stand are minimized. If root rot is present on the site, treatment to minimize the infection rate is required following harvesting. Thus, the harvested openings need to be large enough to facilitate stumping. Mechanical site preparation is often used in this subzone to reduce vegetation competition and create desirable microsites for planting seedlings.

Minimizing the visual impact of harvesting is another reason that small openings were prescribed for this site (BCMOF 1997a). The study site is in the Cariboo Lake Special Resource Development Zone (SRDZ) of the Cariboo-Chilcotin Land Use Plan (Government of BC 1995), and is visible from Horsefly Lake which has high recreational values.

Objectives

The overall objectives of the study are described in detail in the draft working plans for the project (Waterhouse 1999; Weldwood et al. 1995) and are not included in this report. The study included several components, for which other agencies had monitoring responsibility. FERIC's objectives, addressed in this report, were to:

- Determine the economic feasibility of harvesting timber from small canopy openings in wetbelt Douglas-fir stands.
- Document the productivities and costs of harvesting timber from four sizes of small canopy openings.
- Describe and evaluate the equipment and operating practices used during the harvesting phase, and identify operating constraints.
- Compare the productivities and costs of the harvesting phases for each size of opening.

Site descriptions

The study block is located south of Viewland Mountain on the north side of Horsefly Lake, 30 km from the community of Horsefly (Figure 1). The site, in the Interior Cedar-Hemlock moist cool subzone (ICHmk3) (BCMOF 1997b), has an elevation range of 960–1130 m and even terrain with slopes of 0–45%. The majority of the block has a west or southwest aspect. The soils are sand-loam overlaying silt-loam with an average coarse fragment content of 44%. The study block is in the very deep snowpack zone (>200 cm mean annual snowfall).

A timber cruise was completed for the block and a silviculture prescription was completed for each of the twenty openings. Based on this information, the initial stand can be described as 68% Douglas-fir, 18% lodgepole pine (*Pinus contorta*), 9% interior hybrid spruce (*Picea glauca x p.engelmannii*), 2% western red cedar (*Thuja plicata*), and the remaining 3% consisted of subalpine fir (*Abies lasiocarpa*), black cottonwood (*Populus trichocarpa*), white birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*). Trees averaged 32.4 cm in diameter at breast height (dbh), 29.2 m in height, and 0.73 m^3 in merchantable volume. The stand density averaged 598 trees/ha with a total net merchantable volume of 436.3 m^3/ha.

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Study methods

The study block was divided into four treatments based on the size of the harvesting area (canopy opening size): four 0.25-ha openings; four 0.50-ha openings; ten 1.0-ha openings; and two 2.0-ha openings for a total of twenty openings (Figure 2). Productivity and cost data were grouped for each treatment.

Approximately 20% of the study block was harvested, including roads, landings, and openings. Openings were located across and along the contours to provide regeneration with varying amounts and intensities of light, and to cover the range of ecosystem associations and levels of frost drainage.

After harvesting, eleven openings were site prepared (disc trenching) and eight openings were left without site preparation. The remaining opening had root rot (*Armillaria ostoyae)* infections; one half was stumped and the other half was treated with a biological control fungus (*Hypholoma fasciculare*). Planting occurred in the spring of 1998. Permanent deactivation of roads, landings, and skid trails was completed in the summer of 1998. Appendix I contains a complete description of each opening.

Pre- and post-treatment plots were not established by FERIC because researchers from the BCMOF had established several permanent sample plots (Waterhouse 1998).

To obtain shift-level information for each opening, FERIC installed Servis recorders on the feller-buncher, the skidder,

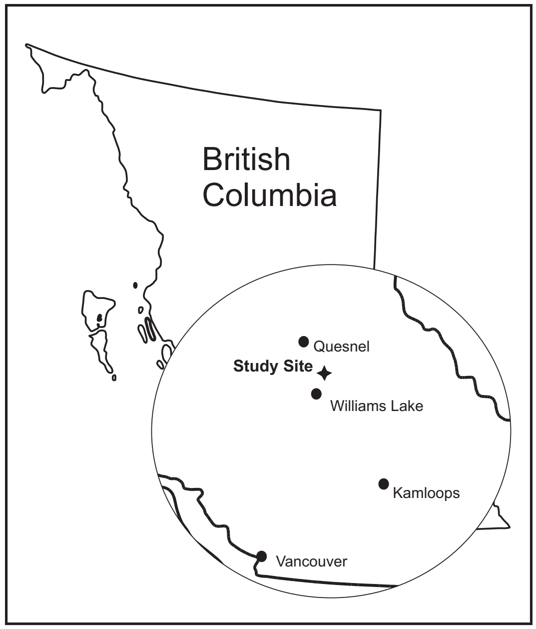


Figure 1. Location of study site.

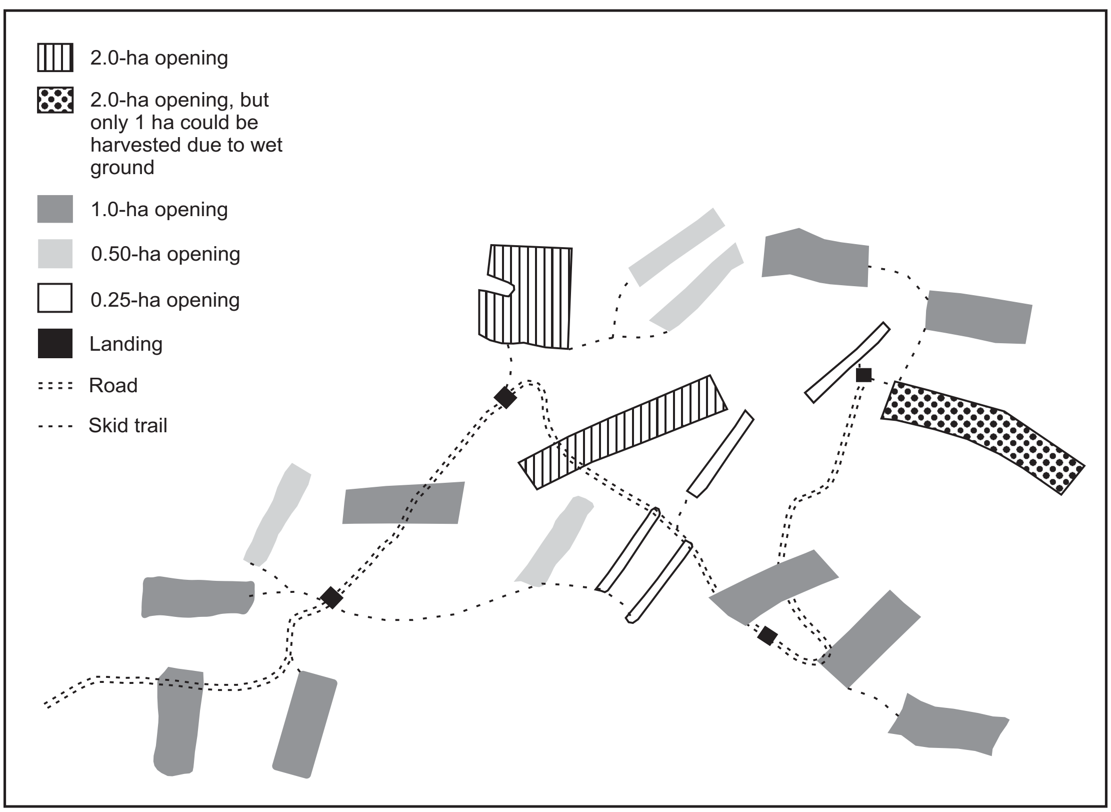


Figure 2. Horsefly Lake study site.

and the processor, and maintained daily crew records. To supplement the shift-level data, specific information on the falling, skidding, and processing cycles was obtained by detailed timing. Harvested wood volumes were obtained from Weldwood's weigh-scale receipts. A sample of felled stems was scaled before skidding to determine piece size for each opening size.

Harvesting costs were calculated using FERIC's standard costing method, which uses IWA wage rates for workers and current purchase prices for equipment (Appendix II). The calculated costs in the study were not those experienced by the contractor, and do not include supervision, overhead, profit, and risk allowances.

Harvesting systems

Weldwood developed the study block to meet the prescriptions and requirements of the researchers from the BCMOF and BCMOE. The boundaries of the openings were marked with paint and flagging tape, and the skid trails were flagged. The main haul road was built for Weldwood by a contractor in the spring of 1996, but skid roads and landings within the study block were constructed by the harvesting contractor just prior to harvesting in the fall of 1997. A network of permanent skid trails was designed to be used for all entries over the entire rotation. Even though opening boundaries were located to accommodate machine-free zones in and around the wetter areas, it was possible to harvest only 50% of Opening 3 owing to wet ground.

The trees were felled with a Timbco T445 feller-buncher and then skidded with a Ranger F668 grapple skidder to one of four landings, where they were processed into short logs by a Denharco 550 processing head mounted on a John Deere 690D LC excavator. A Caterpillar 966C front-end loader sorted, decked, and loaded the logs onto logging trucks for hauling 95 km to Weldwood's plywood plant in Williams Lake or 150 km to Weldwood's sawmill in 100 Mile House.

Two operators operated the feller-buncher for 7 days each. The skidder operated for 11 days and was then replaced by a second Ranger F668 skidder and operator for 18 days. The contractor operated a third skidder during the last 10 days of the project to increase daily production. All equipment involved in the harvesting phase is listed in Appendix II.

During the study, the weather became warmer and wetter, causing the landings and roads to become soft and muddy. The operators moved their machines to drier landings and put chains on the skidder, but eventually had to stop work for five weeks until the roads and landings dried up.

All snags were removed during the falling phase, and non-merchantable deciduous trees (mostly aspen and birch) were stubbed (cut at the highest point the feller-buncher could reach) to become wildlife trees. The top sections of these trees were cut into smaller sections and left at the stump.

Results

Productivities

Productivity in this report is based on productive machine hours (PMH) and not scheduled machine hours (SMH). Utilization rates are calculated as PMH/SMH and ranged from 62 to 95% for individual machines. Falling and skidding productivities by treatment are presented in Tables 1 and 2, respectively.

Tree size, slope, and the number of times the feller-buncher has to change directions or turn around in an opening affect falling productivity. The distance between openings and the length of trail cut to access the opening affect the proportion of time the feller-buncher is available to harvest the openings. The treatment with the highest falling productivity was the 2.0-ha openings at 108.0 m^3/PMH, followed by the 0.25-ha openings at 106.6 m^3/PMH, the 1.0-ha openings at 97.2 m^3/PMH, and the 0.50-ha openings at 79.7 m^3/PMH (Table 1).

Table 1. Falling productivity				
	Opening size			
	0.25 ha	0.50 ha	1.0 ha	2.0 ha
Number of openings in study	4	4	10	2
Falling (PMH)	5.3	13.0	49.9	17.0
Non-mechanical delays (h)				
Walking between openings	3.0	1.7	1.3	0.3
Coffee/lunch	0.3	0.6	2.6	1.5
Talk to supervisor	-	1.3	1.1	-
Total non-mechanical delays	3.3	3.6	5.0	1.8
Mechanical delays (h)				
Service and maintenance	-	0.1	1.4	2.5
Repairs	-	-	1.5	2.0
Total mechanical delays	-	0.1	2.9	4.5
Scheduled machine hours (SMH)	8.6	16.7	57.8	23.3
Total volume harvested (m^3)	565.0	1035.8	4849.6	1836.2
Total area harvested (ha)	1.2	2.2	10.3	3.9
Productivity				
m^3/PMH	106.6	79.7	97.2	108.0
PMH/ha	4.4	5.9	4.8	4.4
Production/8-h shift (m^3)	529	497	669	631
Utilization (PMH/SMH) (%)	62	78	86	73

Although average tree diameter varied from 24 to 51 cm for all species, and slope varied from 7 to 45%, there was no significant difference in tree size or slope among the treatment units. The feller-buncher was able to complete the 0.25-ha openings in two passes, thereby minimizing the amount of time spent turning and maximizing falling time. Due to the steep slope in Opening 9 (1.0 ha), the feller-buncher worked uphill and then walked downhill to start the next strip. Average length of skid trail constructed to access each opening was greatest for the 0.50-ha openings at 104 m, followed by the 0.25-ha openings at 78 m, the 1.0-ha openings at 39 m, and the 2.0-ha openings at 19 m.

Skidding productivity is affected by slope, skidding distance, landing size, and operator technique. During the block development and planning stages, the choice of landing size and location will determine the skidding distance and pattern. The extent of adverse skidding can also be minimized during planning, which in turn minimizes the influence of slope on productivity.

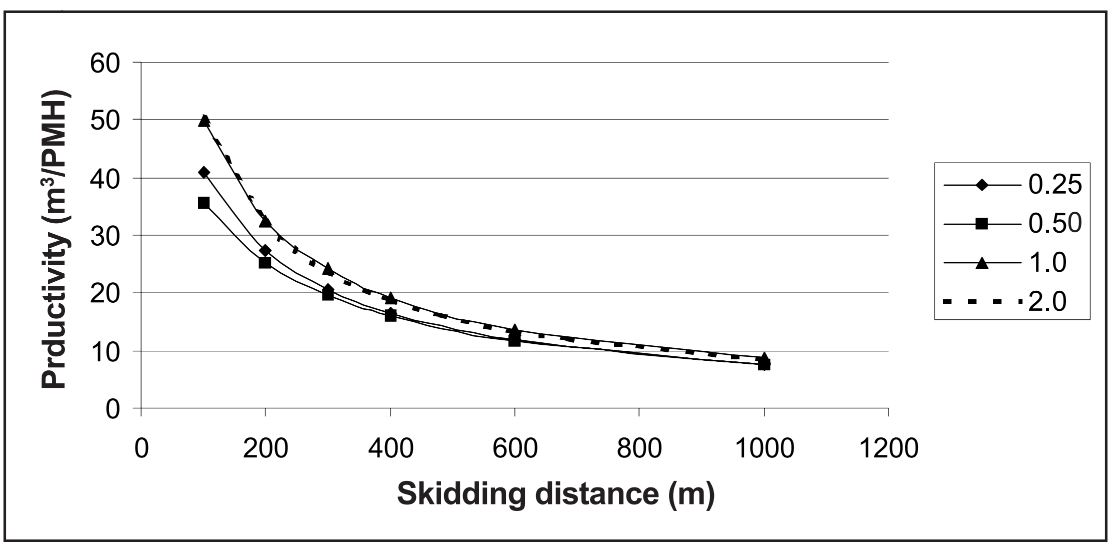
The average distance skidded ranged from 174 to 456 m (Table 2). When one landing became full, the skidder moved to another opening and skidded the stems to a different landing while the first landing was cleared by the loader. There was no significant difference in productivities among the skidder operators. To eliminate the influence of skidding distance on skidding productivity, distances were standardized at 200 m. Figure 3 shows skidding productivity for skidding distances between 100 and 1000 m. Skidding productivity, at 200 m, was higher

Table 2. Skidding productivity

	Opening size			
	0.25 ha	0.50 ha	1.0 ha	2.0 ha
Number of openings in study	4	4	10	2
Skidding (PMH)	18.8	50.9	152.8	57.8
Non-mechanical delays (h)				
Walking between openings	-	0.2	0.9	-
Coffee/lunch	1.0	0.8	5.8	2.5
Talk to supervisor	-	0.5	3.3	1.4
Total non-mechanical delays	1.0	1.5	10.0	3.9
Mechanical delays (h)				
Service and maintenance	-	0.8	4.7	2.3
Repairs	1.0	0.3	4.0	-
Total mechanical delays	1.0	1.1	8.7	2.3
Scheduled machine hours (SMH)	20.8	53.5	171.5	64.0
Total volume harvested (m^3)	565.0	1035.8	4849.6	1836.2
Total area harvested (ha)	1.2	2.2	10.3	3.9
Average skidding distance (m)	456	246	198	174
Productivity				
m^3/PMH	30.1	20.3	31.7	31.8
m^3/PMH (at 200 m) [a]	27.4	25.2	32.5	32.3
PMH/ha	15.7	23.1	14.8	14.8
Production/8-h shift (m^3)	216.7	154.3	225.7	229.0
Utilization (PMH/SMH) (%)	90	95	89	90

[a] Calculated for a standard skidding distance of 200 m.

Figure 3. Skidding productivity and skidding distance.



for the 1.0- and 2.0-ha openings (32.5 and 32.3 m^3/PMH, respectively) than for the 0.25- and 0.50-ha openings (at 27.4 and 25.2 m^3/PMH, respectively) (Table 2).

Productivities and costs for processing short logs were calculated for each landing, not by treatment, because it was not always possible to identify the source of the wood. The processor's productivities and costs depended on the skidder keeping the landings filled with wood to ensure the processor was not idle. The skidder alternated between openings with long skidding distances and openings with short skidding distances to help keep the wood flowing steadily to the landing. The processor's productivity was also affected by its need to move to another landing when the skidded wood supply at its current landing was exhausted, or to avoid impeding loading.

Costs

Appendix II presents machine costs for the harvesting equipment, using the standard FERIC costing formula. These costs illustrate the relative cost differences between the individual pieces of harvesting equipment; they are not the actual costs incurred by the contractor or the forest company.

Average harvesting costs for each treatment are listed in Table 3. Average costs for falling ranged from \$1.17 to \$1.58/m^3, and skidding costs ranged from \$3.15 to \$4.06/m^3. The overall harvesting costs, i.e., for shortlogs processed at the landing, ranged from \$6.70 to \$8.00/m^3. Overall harvesting costs increased slightly as opening size decreased, except for the 0.50-ha openings (Figure 4). Assuming the cost of harvesting the 2.0-ha openings is the base cost, the cost of harvesting the 1.0-ha openings increased

Table 3. Average harvesting costs

Opening size	Falling (\$/m^3)	Skidding (\$/m^3)	Processing (\$/m^3)	Total (\$/m^3)	Cost increase (%)	Machine utilization (%)
0.25 ha	1.18	3.73	2.36	7.27	8.5	82
0.50 ha	1.58	4.06	2.36	8.00	19.4	91
1.0 ha	1.30	3.15	2.36	6.81	1.6	88
2.0 ha	1.17	3.17	2.36	6.70	-	86

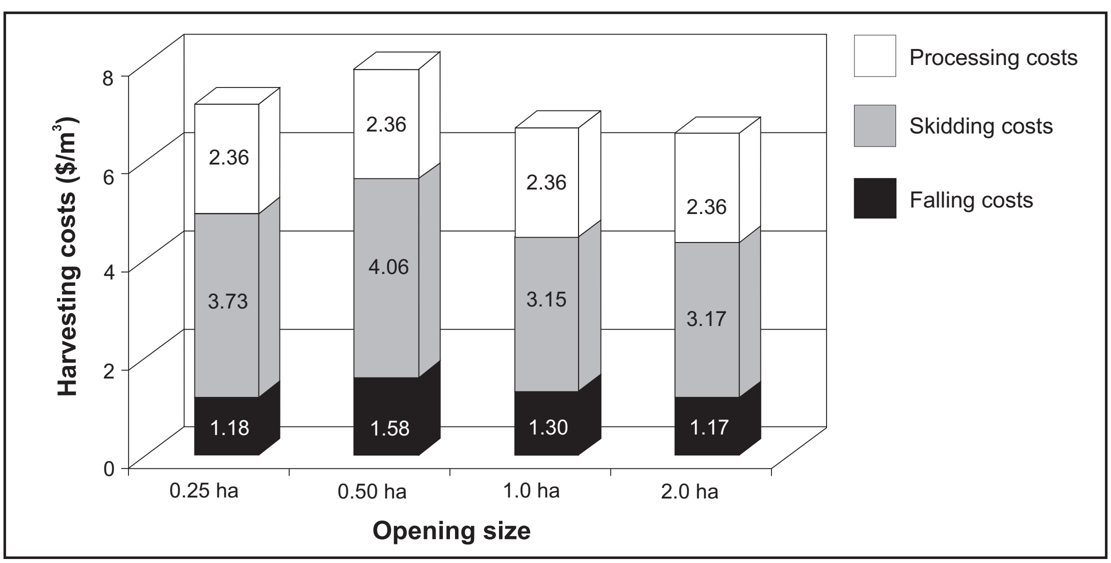


Figure 4. Harvesting costs.

by 2% (Table 3), while the costs of harvesting 0.25-ha and 0.50-ha openings increased by 9 and 19%, respectively.

Costs for planning and layout activities were not included in FERIC's study because of the research nature of the operations. However, Thibodeau et al. (1996) found that planning and layout costs for harvesting small patches were 1.9 to 2.3 times greater than for larger clearcuts owing to their more intensive planning and field work requirements. Mitchell (1996) also found that layout costs for individual tree selection and small openings were almost double that of a conventional clearcut block.

Discussion

Developing a block for partial cutting requires more planning and field work than a conventional clearcut operation with larger opening sizes. All portions of the block must be accessible by the skid-trail system, and the trail pattern must allow skidding to be carried out with acceptable levels of productivity, but without damaging residual trees. Laying out and marking the boundaries for small openings requires more time per cubic metre of wood harvested than for larger openings.

In this study, minimizing the number of landings resulted in some very long skidding distances (up to 500 m). The wood from all twenty openings (8287 m^3) was processed on four landings, leading to some congestion of wood and equipment on the landings. The skidder was required to move to another landing when the current landing became plugged with stems or logs waiting to be loaded onto the trucks. The processor was also required to move to another landing if the skidded wood supply at its current landing was exhausted or if trucks were being loaded. The skidder tried to maintain a steady flow of logs to the landings by alternating between openings with long skidding distances and those with short skidding distances.

Making comparisons in a study such as this one is difficult, because each opening has a unique set of characteristics. Although the data have been grouped by opening size, within each size there were differences in opening shape, slope orientation, ground moisture, distance to the landing, and distance between the openings. Some of these differences were required to meet the research objectives of the BCMOF researchers. Also, because the feller-buncher and skidder operators did not always delineate whether wood originated from trail cutting or opening cutting, it was difficult to separate machine productivities on trails from those for openings. Machine productivities were then estimated based on detailed-timing results.

Based on the detailed-timing data, productivity was highest in the 0.25-ha openings because the feller-buncher was able to complete the openings in two passes, thereby minimizing the amount of time spent turning and maximizing the falling time. The distance between openings and the length of trail cut to access the opening also affected the time the feller-buncher was available to harvest the openings.

During block development, careful planning of the boundaries and skid-trail locations can minimize the influence of slope, skidding distance, and landing size on machine productivity. The number and size of landings will affect the skidding distance and the logistics in maximizing the productivity of the skidder and processor.

In a lower-volume overmature subalpine fir/spruce stand in southern B.C., Mitchell (1996) found productivities for feller-bunchers working in 0.1-ha openings ranged from 55 to 71 m^3/PMH, and skidding productivities for skidders ranged from 27 to 36 m^3/PMH on three trial units. In the same study, the falling productivities for 1.0-ha openings ranged from 31.9 to 107.0 m^3/PMH, and skidding productivies ranged from 24.6 to 39.2 m^3/PMH. Therefore, the productivities for the feller-buncher and skidders in this study at Horsefly Lake are similar to the productivity reported in other FERIC studies of feller-bunchers and skidders in small openings.

Conclusion and Implementation

The treatment with the highest falling productivity was the 2.0-ha openings at 108.0 m^3/PMH followed by the 0.25-ha openings at 106.6 m^3/PMH, the 1.0-ha openings at 97.2 m^3/PMH, and the 0.50-ha openings at 79.7 m^3/PMH.

Skidding productivity was higher for the 1.0- and 2.0-ha openings (32.5 and 32.3 m^3/PMH, respectively) than the 0.25- and 0.50-ha openings (at 27.4 and 25.2 m^3/PMH, respectively).

Processing productivity and costs were calculated for each landing, not by treatment area, because it was not always possible to identify the source of the wood.

Planning and layout activities and costs were not included in the study because of the research nature of the operations. However, a past FERIC study found that planning and layout costs for small patches were 1.9 to 2.3 times greater than for clearcuts due to their more intensive planning and field work requirements.

Average harvesting costs for falling ranged from \$1.17 to \$1.58/m^3, and skidding costs ranged from \$3.15 to \$4.06/m^3. The overall harvesting costs for short logs processed at the landing ranged from \$6.70 to \$8.00/m^3. There was a 2% increase in the cost of harvesting the 1.0-ha openings over the 2.0-ha openings, while the costs of harvesting 0.25-ha and 0.50-ha openings increased by 9 and 19%, respectively.

In this study, opening size had a minimal effect on harvesting productivities and costs. Harvesting of the block by small openings was feasible with some increase in cost (up to 19%) that could be reduced by adding another landing to shorten the skidding distances.

The true significance of the cost differences will depend on the effect of the opening sizes and post-harvest treatments on regeneration performance and mule deer winter habitat. The degree of success of the overall project will not be known until the research components carried out by the other agencies are completed. The final decision on success or failure of harvesting several small openings within one block can only be determined in the long term, after the second and third entries are completed.

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Appendix I

Description of canopy openings [a]

Treatment no.	Opening no.	Area (ha)	Description of moisture regime	Root rot	Orientation [b]	Site preparation
1 (2.0 ha)	1	2.0	zonal	yes	across	50% stump 50% biocontrol
	2	1.9	zonal	no	across	MSP [c]
2 (1.0 ha)	3	1.0 [d]	wet zonal	no	along	MSP
	4	1.1	zonal	no	along	MSP
	5	1.0	zonal	no	along	no
	6	1.0	zonal	no	across	no
	7	1.0	zonal	no	across	MSP
	8	1.0	wet zonal	no	along	MSP
	9	1.0	dry zonal	no	across	no
	10	1.1	dry zonal	no	along	no
	11	1.1	dry zonal	no	along	MSP
	12	1.0	zonal	no	across	MSP
3 (0.50 ha)	13	0.6	zonal	no	along	MSP
	14	0.6	zonal	no	along	MSP
	15	0.5	dry zonal	no	across	MSP
	16	0.5	dry zonal	no	across	no
4 (0.25 ha)	17	0.3	zonal	no	across	MSP
	18	0.3	zonal	no	across	MSP
	19	0.3	dry zonal	no	across	no
	20	0.3	zonal	no	across	no

[a] Based on Weldwood et al. 1995 and Waterhouse 1999.
[b] With respect to the contour.
[c] Mechanical site preparation.
[d] Opening was originally 2.0 ha, but was reduced by 50% owing to wet ground.

Appendix II

Machine costs: harvesting equipment [a]

	Timbco T445 feller-buncher	Ranger F668 grapple skidder	Denharco 550 processor, no carrier	John Deere 690D LC excavator, carrier only
OWNERSHIP COSTS				
Total purchase price (P) $	537 000	285 000	132 500	182 000
Expected life (Y) y	4	5	5	5
Expected life (H) h	12 000	10 000	15 000	15 000
Scheduled h/y (h)=(H/Y) h	3 000	2 000	3 000	3 000
Salvage value as % of P (s) %	30	30	25	25
Interest rate (Int) %	10	10	10	10
Insurance rate (Ins) %	3	3	3	3
Salvage value (S)=(P•s/100) $	161 100	85 500	33 125	45 500
Average investment (AVI)=((P+S)/2) $	349 050	185 250	82 813	113 750
Loss in resale value ((P-S)/H) $/h	31.33	19.95	6.63	9.10
Interest=((Int•AVI)/h) $/h	11.64	9.26	2.76	3.79
Insurance=((Ins•AVI)/h) $/h	3.49	2.78	0.83	1.14
Total ownership costs (OW) $/h	46.45	31.99	10.21	14.03
OPERATING AND REPAIR COSTS				
Fuel consumption (F) L/h	25	25	-	25
Fuel (fc) $/L	0.45	0.45	-	0.45
Lube & oil as % fuel (fp) %	15	15	-	15
Annual tire consumption (t) no.	-	2	-	-
Tire replacement (tc) $	-	3 200	-	-
Track & undercarriage replacement (Tc) $	33 000	-	-	33 000
Track & undercarriage life (Th) h	6 000	-	-	6 000
Annual operating supplies (Oc) $	-	-	5 000	-
Annual repair and maintenance (Rp) $	85 920	45 600	21 200	36 400
Shift length (sl) h	8	10	10	10
Total wages (W) $/h	24.21	21.10	-	20.76
Wage benefit loading (WBL) %	35	35	-	35
Fuel (F•fc) $/h	11.25	11.25	-	11.25
Lube and oil ((fp/100)•(F•fc)) $/h	1.69	1.69	-	1.69
Tires ((t•tc)/h) $/h	-	3.20	-	-
Track & undercarriage (Tc/Th) $/h	5.50	-	-	5.50
Operating supplies (Oc/h) $/h	-	-	1.67	-
Repair and maintenance (Rp/h) $/h	28.64	22.80	7.07	12.13
Wages & benefits (W•(1+WBL/100)) $/h	32.68	28.49	-	28.03
Prorated overtime ((1.5•W-W)•(sl-8)•(1+WBL/100))/sl) $/h	-	2.85	-	2.80
Total operating costs (OP) $/h	79.76	70.27	8.73	55.90
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	126.21	102.26	18.95	75.43 94.38 [b]

[a] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. They do not include supervision, profit and overhead, and are not the actual costs for the contractor or company.

[b] Combined cost of processor and carrier.