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HARVESTING COASTAL SECOND-GROWTH FORESTS: HAND FALLING AND SKYLINE YARDING

TN239

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Abstract

Between December 1993 and March 1994, the Forest Engineering Research Institute of Canada (FERIC) monitored hand-falling and skyline-yarding operations in a 9.6-ha second-growth stand of Douglas-fir, western hemlock, and western redcedar in Coastal British Columbia. The study measured falling and skyline yarding productivities, identified factors influencing productivity, recorded extracted volumes by timber grades, and conducted post-harvest site assessments. Simple productivity prediction models were developed for falling only, falling and processing, and skyline yarding.

Introduction

In the fall of 1991, the Forest Engineering Research Institute of Canada (FERIC) and the Faculty of Forestry at the University of British Columbia (UBC) initiated a four-year cooperative project to evaluate harvesting systems for clearcutting Coastal second-growth stands in British Columbia. Funding for the project was obtained through the Canadian Forest Service under the Canada/British Columbia Forest Resource Development Agreement (FRDA II). The overall objectives of the project were to develop productivity and cost prediction models for common harvesting systems operating in Coastal second-growth stands, as well as develop a prediction model of harvested volumes by sorts based on pre-harvest cruise data. Data for the models were collected during a two-year field study program, supplemented by existing research of second-growth harvesting methods.

This report is the second in a series of FERIC publications about case studies conducted to document the performance of harvesting systems in Coastal second-growth stands (Andersson and Jukes 1995). It presents the results from a hand-falling and skyline-yarding operation in a second-growth stand harvested between December 1993 and March 1994 near Sechelt, on British Columbia's mainland coast north of Vancouver.

The specific objectives of this case study were to determine falling and yarding productivities and costs, identify factors influencing productivity, record volume by timber sort produced from the stand, and measure post-harvest wood waste and soil surface conditions. Data on volume by sort, post-harvest slash, and soil disturbance were collected primarily for a later publication that will present an overall analysis of harvesting systems. These data are therefore only summarized in this report, and not tied to the performance of the hand-falling and skyline-yarding operations.

Site Description

The 9.6-ha study site located 15 km north of Sechelt, was a 100-year old stand of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western redcedar (*Thuja plicata* Donn), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and red alder (*Alnus rubra* Bong.). After the site was harvested in the 1890's, the second-growth trees had established themselves naturally. The management objectives for the site were to clearcut the stand to prevent the loss of merchantable timber to root rot (20% of area infested by *Phellinus weirii*),

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to treat the existing area of infection, and to reforest the area with Douglas-fir and cedar to produce merchantable timber on a 90-year rotation.

The terrain in the block was generally concave in shape, and slopes ranged from 5 to 20%. Two intermittent Class IV streams[1] flowed through the block (Figure 1). Harvesting was restricted to cable systems because a 1.5-ha wet depression on the lower portion of the block precluded the use of ground-based equipment.

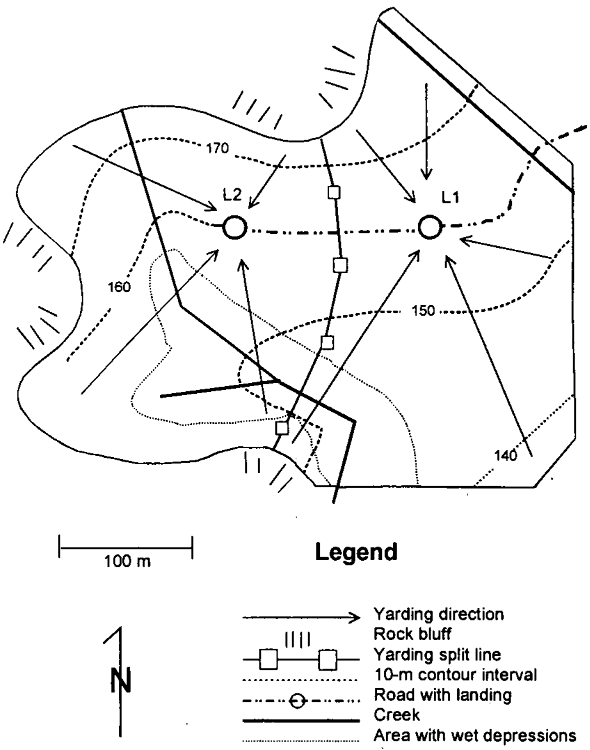

Figure 1. Sechelt study block.

Average gross stand volume of the block was estimated to be 831 m^3/ha (Table 1). The diameter at breast height (dbh) of merchantable trees ranged from 13 to 110 cm, with 46% of the trees being <30 cm. However, trees <30 cm dbh represented only about 7% of the total stand volume, while 30% of the volume was contained in the largest 6% (>70 cm dbh) of the trees in the stand (Figure 2).

System Description

The trees on the site were hand felled and bucked into specific log lengths (Appendix I) by two highly skilled fallers (Figure 3). Falling began in mid-December 1993, and was completed at the end of January 1994. The fallers normally worked 6.5 h/day, 5 days/week, but adverse weather conditions, especially high wind, occasionally reduced the working hours.

Following the falling operation, a Washington SLH78 swing yarder extracted the logs to roadside (Figure 4). Yarding commenced in early February, and was completed at the end of March 1994. The yarder was rigged as a running skyline, and equipped with a Berger mechanical slack-pulling carriage. The dropline normally had four chokers. A mobile backspar (Koehring Bantam 366 excavator) was used for half the area, and standing trees were rigged as backspars for the rest of the study block.

[1] No fish present. Stream gradient is usually >20%. Management objective is to maintain sufficient channel integrity to protect Class I and II (fish bearing) reaches that may be affected by accelerated transport of sediment or debris (BCMOF 1993).

Table 1. Average Pre-Harvest Stand Characteristics of Study Site

	Cedar	Douglas-fir	Hemlock	Alder	All trees
Merchantable trees[a]					
dbh (cm)	31	41	31	29	35
Total height (m)	28	33	30	n/a	31[b]
Merchantable height (m)	24	27	23	n/a	25[b]
Volume/tree (m^3)	0.99	2.11	1.26	0.66	1.48
Trees/ha (no.)[c]	180	220	140	20	560
Volume/ha (m^3)[d]	177	466	172	16	831
Snags					
dbh (cm)	100	23	15	28	26
Stems/ha (no.)[c]	<10	30	20	30	80
Unmerchantable trees (10-12 cm dbh)					
Trees/ha (no.)[c]	50	10	10	<10	70

[a] Live, sound trees with a dbh ≥13 cm. [b] Excludes red alder. [c] Rounded to nearest 10 trees/ha. [d] Differences due to rounding.

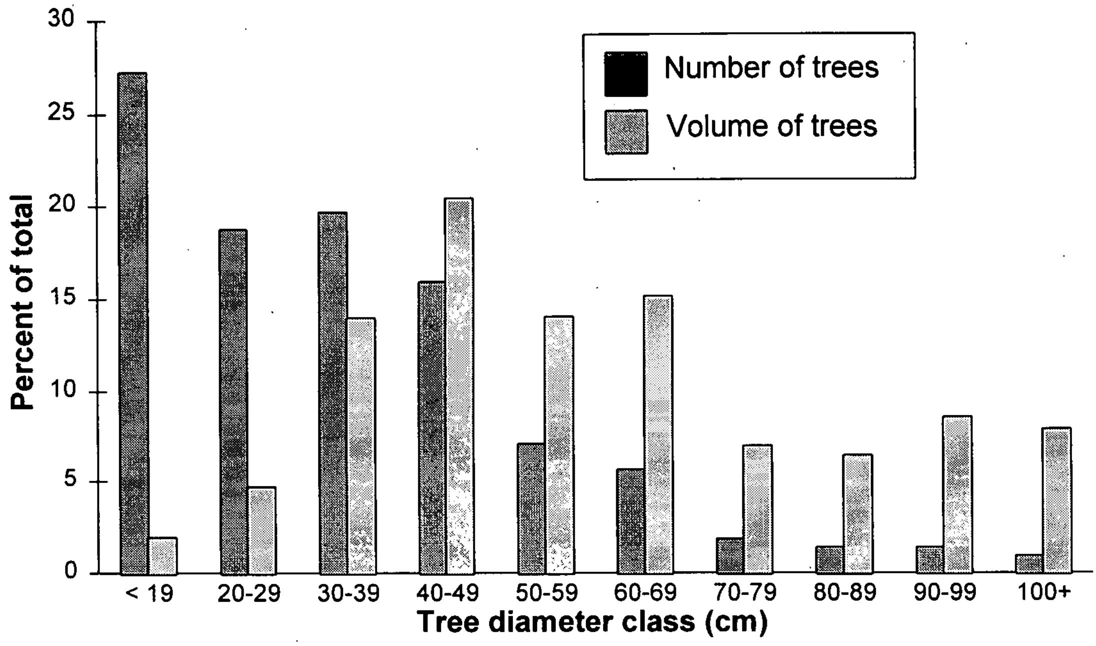

Figure 2. Distribution of number of stems and total merchantable volume of stems, by diameter class.

Figure 3. Hand-falling operation at Sechelt.

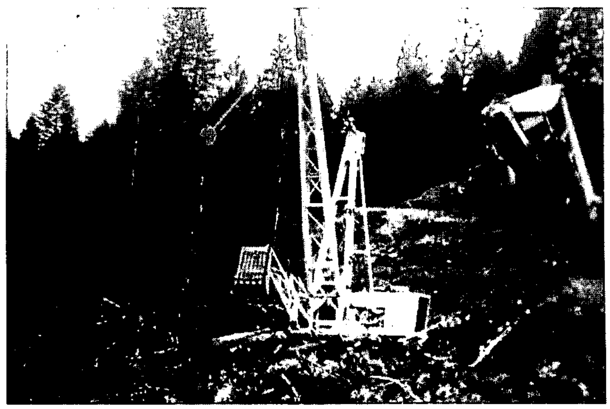

Figure 4. Washington SLH78 swing yarder and Chapman CH172 log loader at Sechelt.

A Chapman CH172 log loader removed logs from the yarder decking area, and loaded log trucks. Two log trucks, each normally making two or three trips per day, hauled the logs from the site to a sortyard near Gibsons, approximately 60 km away.

The yarding operation utilized five people; one hooktender (who also set chokers), one chokersetter, one chaser, one yarder operator, and one loader operator. However, not all the members of the crew were present at all times. The hooktender and the yarder operator were the same individuals who had felled the setting. The crew typically worked 8 h/day, 5 days/week.

Study Methods

Prior to falling, FERIC cruised the study site using 200-m^2 fixed area sample plots located in a grid pattern spaced 70-m apart (4% of the area). At each plot, dbh, crown ratio, and species were recorded for each tree, and tree heights were recorded for a selected number of trees.

Data on the falling and yarding operations were collected using shift-level and detailed-timing techniques.

The fallers completed daily activity reports that recorded scheduled and productive work times, as well as reasons for non-working time. In addition, 20 h of detailed timing were conducted on the falling operations. The detailed-timing studies recorded the dbh and species of trees felled, and the time for the various work elements.

A DSR Servis recorder was used to monitor the yarder's scheduled (SMH) and operating machine hours (OMH). The yarder operator also completed shift-level reports noting reasons for non-operating times and the number of pieces yarded per day. Approximately 47 h of detailed-timing data were collected on the yarding operation. Each detailed-timing study recorded operating conditions, time for various work elements, yarding distance, and number of pieces yarded per turn.

Two different data sets were used to determine productivity. Net productivity is based on shift-level data and scaled (net) volume, while gross productivity is based on detailed-timing data and gross merchantable volume of sampled trees or stems. The two methods may therefore produce different numerical results, because of the difference between gross and net volumes, and between OMH and productive machine hours (PMH).[2]

All logs were scaled and graded by licensed scalers at a sortyard. Most of the pieces yarded on any given day were delivered the same day to the sortyard. Therefore, the average piece size delivered on the days of detailed-timing studies was assumed to be representative, although the chaser did some bucking of the yarded pieces at the landing.

The harvesting costs were determined using FERIC's standard costing formula (Appendix II). These costs do not necessarily reflect the actual operating costs incurred by the contractor.

The line intercept method (Sutherland 1986) was used to measure slash and soil disturbance following harvesting. The plots were located 70-m apart in a grid pattern. The slash survey measured all sound pieces >9.5 cm in diameter, regardless of length, and did not differentiate between avoidable and unavoidable logging waste. Soil disturbance was defined as occurrences of exposed mineral soil regardless of area disturbed, and alterations to the ground as a result of construction of roads or trails.[3]

Results

Results presented in this report are based on limited data for operating conditions in a specific Coastal second-growth stand; caution must therefore be exercised when interpreting the results of this study and when comparing them with those of other studies.

Recovered Volume. The scaled volume delivered from the study site was 8415 m^3. Piece size ranged from 0.002 to 11.644 m^3, with an average of 0.65 m^3. Sixty-one percent of the pieces, representing 18% of the total volume, were <0.50 m^3, while only 4.5% of the pieces contained more than 2.0 m^3, but represented 26% of the overall volume (Figure 5).

The recovered volume was 7.7% (604 m^3) more than the estimated volume from the cruise data. However, the cruise information overestimated the volume of cedar by 40%, and underestimated the volumes of Douglas- fir and hemlock by 24% and 3% respectively. The comparison excludes the volume measured on the site in the post-harvest residue survey. FERIC's survey estimated the total residue volume at 174 m^3 (18.1 m^3/ha), of which 87% (15.8 m^3/ha) was from pieces <15 cm in diameter. Pieces <3.0-m long accounted for 40% (7.3 m^3/ha) of the total volume.[4]

Figure 6 shows the distribution of the recovered volumes by sorts and species. Most of the timber was classified as Saw Gang G1 (3646 m^3), and Merch (2163 m^3). Approximately 9% (754 m^3) of the volume was from pieces <15 cm in diameter.

Falling Operation. Seventy-two man-days (468 scheduled hours) were required to fall the study site. Actual working time was estimated to be 380 h. Of the lost time (88 h), 81% was due to adverse weather conditions. Average net productivity was 117 m^3/man-day or 22.1 m^3/working hour. The cost to fall the study stand was \$3.24/m^3, based on a daily operating cost of \$379/day.

Faller productivity, determined in four detailed-timing studies, ranged from 21.7 to 29.6 m^3/PMH (Table 2). The higher hourly and man-day productivities recorded in the detailed-timing studies compared to the shift-level studies are attributed to lost time that did not occur during the detailed studies, such as for adverse weather conditions, coffee and lunch breaks. Consequently, the portion of effective working time in relation to 6.5-h scheduled work time/day was high (87%).

Detailed-timing data showed that 24% of the productive time was spent felling and 39% processing, while walk-in-stand and fuel/file chain saws each accounted for about 11% of the time. Both the falling and

[2] PMH includes all activities required to perform a specific operation (e.g. falling or yarding), but in this study excludes delays and non-essential activities. OMH includes delays <15 min/occurrence.
[3] Soil disturbance data were collected prior to the enactment of the British Columbia Forest Practices Code.
[4] The official BCMOF survey determined a cut control residue volume of 14.1 m^3/ha, of which 8.5 m^3 could have been utilized.

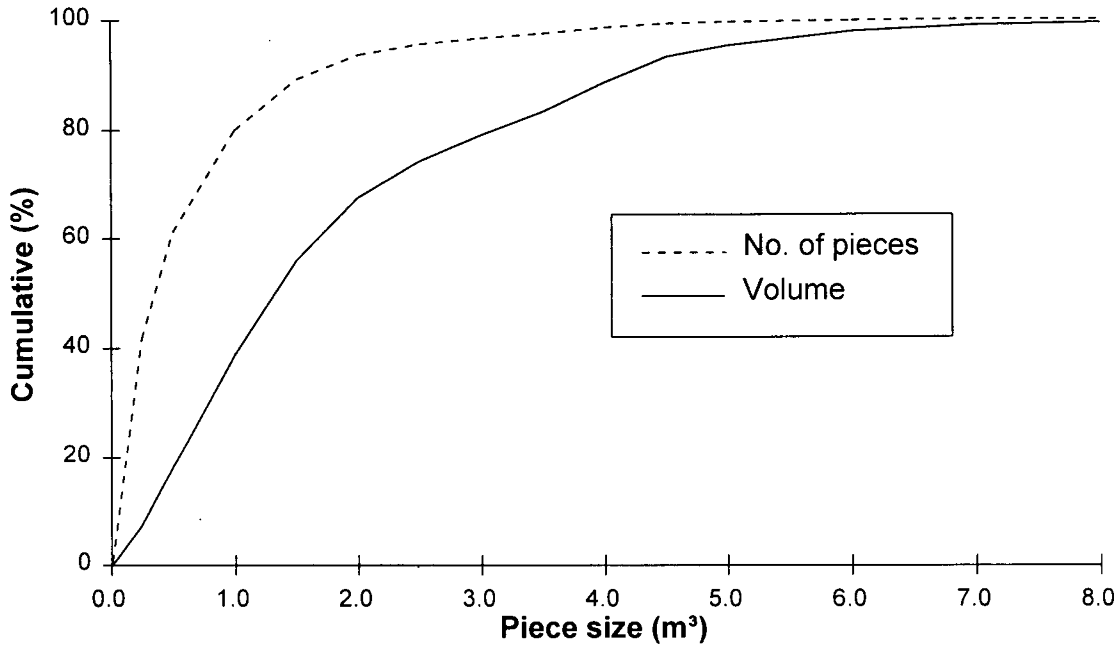

Figure 5. Cumulative percent of pieces and volume, by piece size.

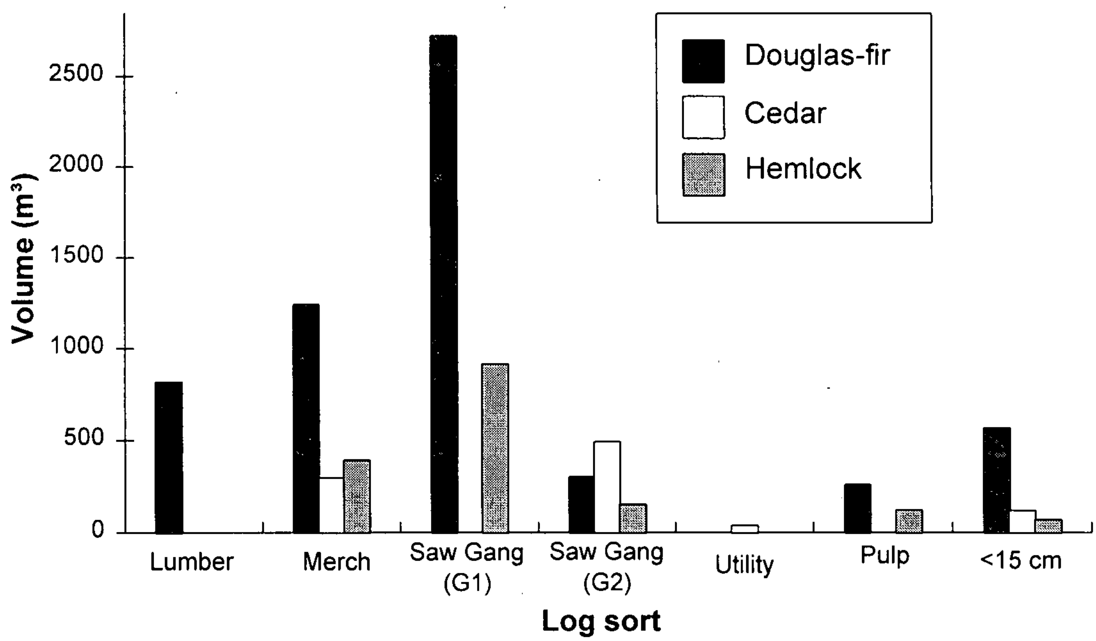

Figure 6. Distribution of scaled volume, by species and log sort.

processing times were found to increase with tree size, which resulted in fewer trees felled per hour. However, the increase in tree volume with increased tree size more than offset the longer processing time per tree, resulting in an increase in volume productivity. Factors influencing walk-in-stand time could not be determined with this data. In theory, walking time per tree should increase with distance between trees and adverse terrain conditions. However, FERIC observed that the fallers did not necessarily walk to the closest tree from the previously felled tree, because the lean of the trees often influenced the order in which the trees could be safely and efficiently felled. The amount of walk-in-stand time may therefore be very difficult to determine based solely on stand data.

No significant differences were found in the time to fall and process cedar, Douglas-fir, and hemlock, although the crown ratio varied with species; cedar typically had the highest crown ratio, while Douglas-fir

Table 2. Summary of Detailed-Timing Studies: Hand Falling

	Study number				
	HF 1	HF 2	HF 3	HF 4	All
Observed time (h)	5.3	5.2	4.9	4.5	19.9
Average stand characteristics					
Species distribution [a]	$df_4hw_3cw_3$	$hw_6cw_2df_2$	$df_6hw_3cw_1$	$df_7hw_2cw_1$	$df_5hw_4cw_1$
Merchantable tree dbh (cm)	32	35	36	35	34
Tree volume (m^3/tree)	1.12	1.64	1.48	1.60	1.42
Duration of work elements					
Plan work (min/tree)	0.05	0.05	0.07	0.06	0.06
Fell (min/tree)	0.74	0.87	0.76	1.02	0.84
Process (min/tree)	1.41	1.40	1.10	1.73	1.39
Walk-in-stand (min/tree)	0.31	0.38	0.42	0.40	0.38
Fell-to-waste (min/tree)	0.11	0.12	0.12	0.19	0.13
Other work (min/tree)	0.18	0.13	0.15	0.16	0.15
Fuel/file chain saw (min/tree)	0.29	0.37	0.49	0.28	0.36
Total productive (min/tree)[b]	3.09	3.32	3.12	3.83	3.31
Delays (min/tree)	0.06	0.51	0.14	0.11	0.20
Total observed (min/tree)[b]	3.15	3.83	3.25	3.95	3.50
Productivity					
Trees/PMH (no.)	19.4	18.1	19.2	15.7	18.1
Volume/PMH (m^3)	21.7	29.6	28.5	25.1	25.7
Volume/man-day (m^3)[c]	128	154	164	146	146

[a] Species distribution based on total volume, e.g. $df_4hw_3cw_3$ = 40% Douglas-fir, 30% western hemlock, and 30% western redcedar. [b] Differences due to rounding. [c] Assumes 0.5-h total walk in/out time per 6.5-h shift in addition to delays recorded during detailed timing, but excludes other lost time.

had the lowest. However, the falling and processing time per tree was also influenced by the need to use wedges during falling, and differences in bucking specifications. The sample size of larger diameter trees was also relatively small, making it difficult to detect potential differences in falling and processing times between the species.

While FERIC did not actually measure the amount of breakage that occurred during the falling operation, FERIC did make observations about the number of merchantable stems that broke, as they fell to the ground. Based on this, it was concluded that little stem breakage occurred during falling. The low breakage is attributed to the skill and care the fallers took to direct the fall of the trees. Bucking the stems into log lengths at the falling site is also believed to reduce breakage from falling trees because there is less chance for shorter logs than full-length stems to be suspended between terrain peaks.

Figure 7 shows the predicted productivity and falling cost for falling only, and falling and processing trees as functions of gross merchantable tree size (m^3/tree). While factors other than tree size also influence faller productivity, the models are believed to provide a fair estimate of hand-falling productivity in second-growth stands. The productivities predicted in the models are similar to those suggested by Peterson (1987) in a study of hand falling in second-growth stands on Vancouver Island.

Skyline Yarding Operation. Not all wood was extracted to roadside by the swing yarder.[5] It is estimated that 7215 m^3 were yarded by the Washington yarder, while the remaining volume was brought to roadside by an excavator-forwarder and a skidder during the road construction.

Yarding took 46 shifts (386.6 SMH) during which the yarder worked 318.9 OMH. Most downtime was related to mechanical delays: 27.8 h and 20.4 h of repairs to the machine and rigging respectively, 15 h of wait for repair, and 4.5 h of non-mechanical delays.

[5] Scale records show that 30 truck loads, totalling 1196 m^3 or 1819 pieces, were delivered to the sortyard prior to the first day of yarding. Also, some wood was decked at roadside when the yarder was moved into the area. In addition, 255 pieces, or 4.2 m^3, were extracted in a clean-up operation (and delivered to the sortyard in a dump truck) after the yarder was moved from the site.

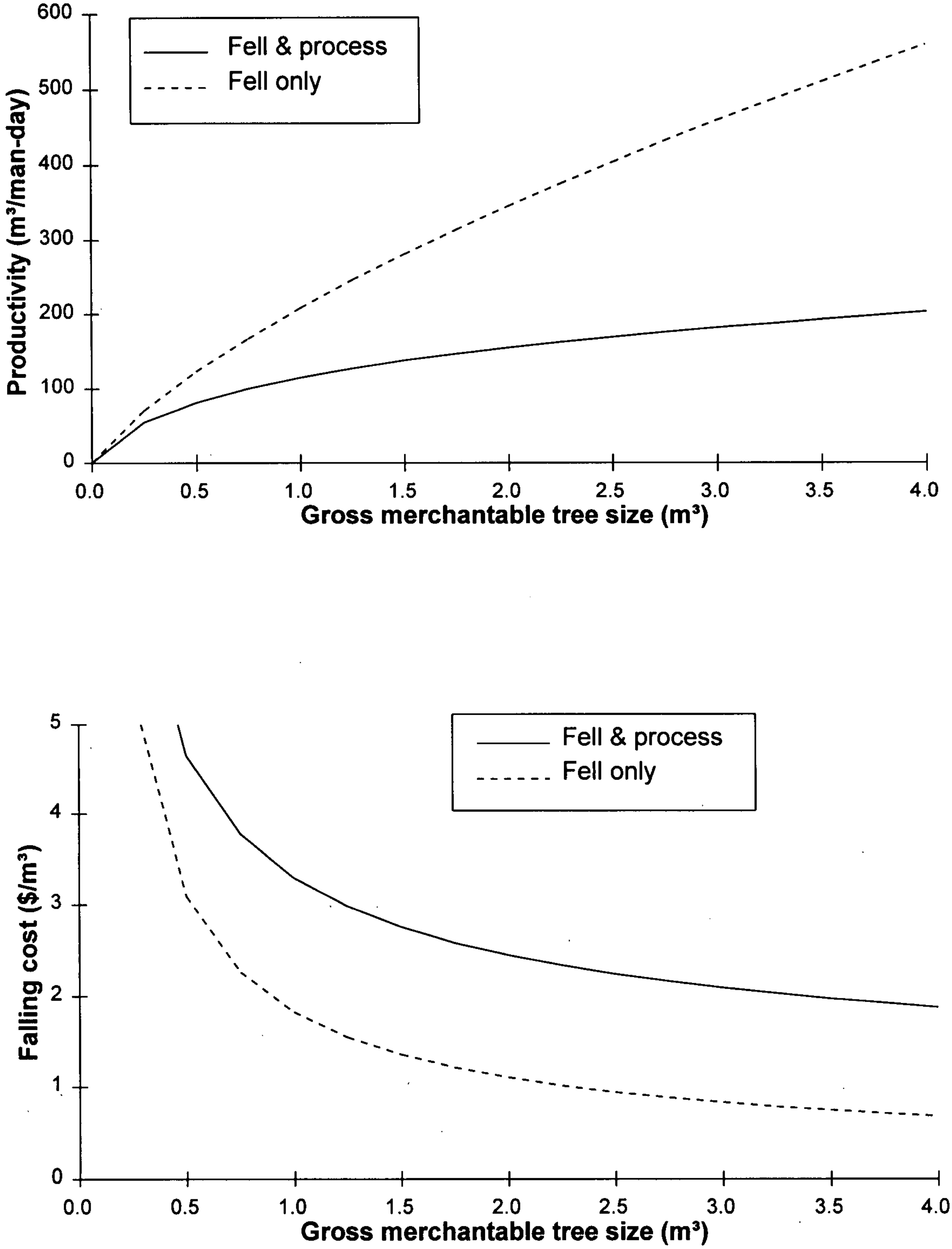

Figure 7. Predicted faller-day productivity (top) and falling cost (bottom), as a function of gross merchantable tree volume.

Productivity, based on shift-level reports, averaged 22.6 m^3/OMH (34 pieces/OMH) or 157 m^3/shift (236 pieces). The external yarding distance ranged between 40 and 200 m, and the average yarding distance for the cutblock was estimated to be 90 m. FERIC determined the cost to yard and load logs to be $13.14/$m^3$ (based on operating cost with used yarder, see Appendix II) and $6.43/$m^3$, respectively.[6]

The productivity of the yarder, when equipped with four chokers and manned by two chokersetters, ranged in seven detailed-timing studies from 22.1 to 34.4 m^3/PMH. One study was also conducted with two chokers and one chokersetter. In this study, the yarder averaged 23.4 m^3/PMH (Table 3).

The variation in yarder productivity measured in the detailed-timing studies was associated primarily with differences in yarding distance, amount of clearance available between the ground and the skyline carriage, and turn size (m^3/turn). In- and out-haul times increased with increased yarding distance. In-haul time was sometimes also affected by poor deflection, which reduced in-haul speed or caused logs to get hung up on stumps or other ground obstacles. Turn size ranged from one to eight pieces, but most turns (47%) contained four pieces. Average turn size was estimated to be 2.7 m^3, based on an average piece size of 0.67 m^3.

Delay times (excluding lunch breaks) averaged 1.17 min/turn or 23% of the productive time. Five major mechanical failures to the rigging accounted for 79% of the observed delay time, while 10% of the delay time was made up of short mechanical delays (such as checking the yarder and replacing chokers or other rigging components). Most non-mechanical delays were short, except for one event when a tailhold stump was pulled.

The number of chokers influenced the unhooking time: for 4-choker turns, the average unhooking time by the chaser was 0.77 min, compared to 0.41 min for 2-choker turns. Some turns were unhooked by the yarder operator rather than by the chaser. This increased the unhooking times for 4-choker turns from an average of 0.77 min/turn to 1.29 min/turn.

The time required to change yarding roads (move time) ranged from 5 to 63 min/move. Move time varied depending on what was required to make the move. Shortest move times occurred when only the mobile backspar was moved (about 5 min/move). In situations where the yarder moved and the guylines were re-positioned, the move time ranged from 18 to 36 min and averaged 25 min. The longest move time (about 60 min) occurred when the rigging was moved between backspar trees. Overall, moving time of the yarder averaged 0.48 min/turn, or constituted 9.4% of total productive time.

The frequency of the yarder moves was influenced by the length of the skyline road and the concentration of wood along these roads. The yarder averaged 52 turns (ranging from 32 to 96) per 100-m skyline road. The average number of pieces yarded was 200, but ranged from 97 to 396/100-m skyline road. Figure 8 shows four productivity prediction models for the Washington SLH78 swing yarder as a function of yarding distance.[7,8] The models are intended only to show the influence of yarding distance and crew size/number of chokers on productivity, and should not be regarded as general productivity models for swing yarders. Figure 8 shows that the productivity of yarder operations with four chokers and two chokersetters would be 30-50% higher than that of yarder operations with two chokers and one chokersetter. Operations without a chaser will produce approximately 10-15% less volume than operations with chasers. However, smaller yarding crews have lower operating costs, therefore the comparison between yarding operations with different crew sizes must be done in a cost analysis.

Figure 9 show the predicted yarding costs for crew size/number of chokers for both a used and a new swing yarder.[8,9] It shows that yarding cost for operations using four chokers and two chokersetters is 20-40% lower than that of operations using two chokers and one chokersetter (depending on yarding distance and age of machine). However, eliminating the chaser from a yarding crew (assuming that the chaser is needed only to unhook the turn) has little or no real impact on the yarding cost.

The analysis also shows the cost advantage of purchasing a used yarder rather than a new yarder. The example in Figure 9 shows a cost advantage of between $1.10 and $2.60/$m^3$ (about 10-15%) depending on crew size and yarding distance. However, used yarders are likely to have more mechanical down time and require more maintenance, and thus would not be able to handle the same daily and annual production as new yarders.

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[6] It is assumed that the loader operated the same number of hours as the yarder, and that average loader productivity was the same as that of the yarder (i.e. 18.7 m^3/SMH).

[7] Assumes an average move time of 24.7 min/occurrence (average of all moves in the study), an average of 200 pieces/100-m yarding road, and minor delays being 3.7% of the yarder's productive time.

[8] The data presented in Table 3 includes all turns and have been re-analyzed to compare productivity with and without a chaser.

[9] FERIC normally calculates costs based on the purchase price of a new machine. However, many used yarders similar to the one monitored and suitable for second-growth timber are available for <$150 000 (see Appendix II).

Table 3. Summary of Detailed-Timing Studies: Washington SLH78 Swing Yarder.

	Study number							
	SY 1	SY 2	SY 3	SY 4	SY 5	SY 6	SY 7	SY 8
Observed time (h)	4.6	7.3	5.9	4.8	5.7	7.5	7.5	4.0
Average operating conditions								
Yarding distance (m)	140	120	100	110	150	110	40	80
Piece size (m^3)	0.62	0.74	0.52	0.52	0.57	0.59	0.70	0.73
Chokers (no.)	4	4	4	4	4	4	4	2
Chokersetters (no.)	2	2	2	2	2	2	2	1
Duration of work elements								
Out-haul (min/turn)	0.55	0.47	0.39	0.43	0.49	0.45	0.25	0.32
Set turn (min/turn)	2.09	2.69	2.31	2.24	2.49	2.59	2.16	1.57
In-haul (min/turn)	1.32	1.06	0.88	1.07	1.06	1.21	0.60	0.61
Deck (min/turn)	0.13	0.16	0.20	0.18	0.19	0.14	0.19	0.20
Unhook (min/turn)	0.80	0.86	0.85	0.87	0.64	0.76	0.84	0.41
Move (min/turn)	0.11	0.00	0.41	0.09	0.60	1.22	0.67	0.70
Other work (min/turn)	0.03	0.00	0.00	0.00	0.00	0.07	0.14	0.03
Total productive (min/turn)[b]	5.04	5.22	5.05	4.88	5.47	6.45	4.86	3.84
Delays (min/turn)	0.32	0.06	0.37	0.15	0.12	0.30	0.10	0.07
Total observed (min/turn)[b]	5.36	5.28	5.42	5.03	5.59	6.75	4.96	3.91
Average turn size								
Pieces (no.)	4.0	3.7	3.9	3.8	4.3	4.0	4.0	2.1
Volume (m^3)[a]	2.5	2.7	2.0	2.0	2.4	2.4	2.8	1.5
Productivity								
Turns/PMH (no.)	11.9	11.5	11.9	12.3	11.0	9.3	12.3	15.6
Pieces/PMH (no.)[b]	48	42	47	46	47	37	49	32
Volume/PMH (m^3)[a,b]	29.9	31.1	24.2	24.0	26.6	22.1	34.4	23.4

[a] Based on average piece size of delivered wood on the day of the detailed-timing study. [b] Differences due to rounding.

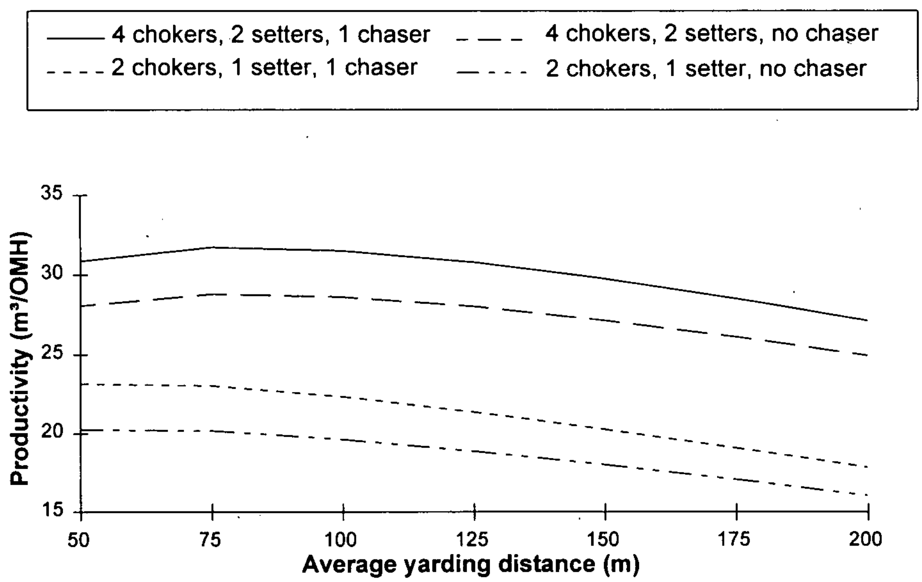

Figure 8. Predicted productivity for Washington SLH78 swing yarder, for crew size and number of chokers, as a function of average yarding distance.

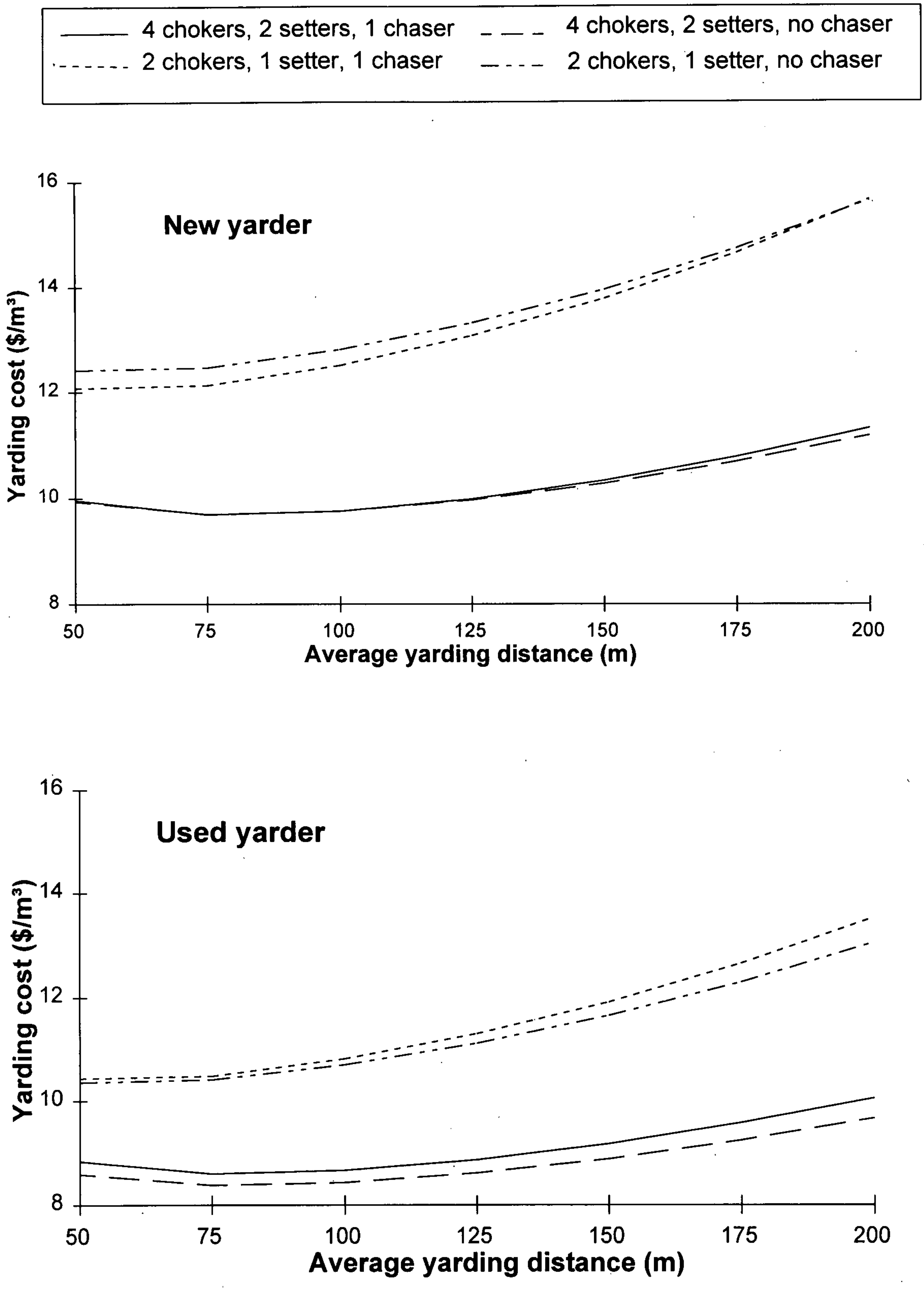

Figure 9. Predicted yarding cost with new and used Washington SLH78 swing yarders, for crew size and number of chokers, as a function of average yarding distance.

Post-Harvest Soil Disturbance. Table 4 summarizes the results of FERIC's post-harvest soil disturbance survey. Mineral soil exposed by yarding was found to be 7.4% of the total area, while alterations to the soil surface from rehabilitating road and the backspar trails accounted for 3.8% of the area. However, all harvesting activities and the soil disturbance survey were conducted prior to the British Columbia Forest Practices Code being enacted, and thus the results of the soil disturbance survey should not be considered in context of the new code. Because delimbing and bucking of the stems were done at the stump area, very little debris accumulated at roadside. The area covered with slash represented 6.6% of the total area, of which 23% was found to be at roadside.

Summary and Conclusions

Between December 1993 and March 1994, FERIC, in cooperation with the Faculty of Forestry at University of British Columbia, monitored a hand-falling and skyline-yarding operation in a 9.6-ha second-growth stand near Sechelt on British Columbia's mainland coast north of Vancouver. Pre-harvest cruise information estimated the 100-year-old stand—comprised primarily of Douglas-fir, western hemlock, western redcedar, and red alder—to average 831 m³/ha or 560 trees/ha. Results of the study are based on limited data for operating conditions in a specific Coastal second-growth stand; caution must therefore be exercised when comparing the performance of this harvesting operation with information presented in other studies.

Total volume extracted from the site was 8415 m³ (877 m³/ha), of which 43 and 26% was Saw Gang G1 and Merch sorts, respectively. Approximately 9% of the volume was from pieces <15 cm in diameter. Average faller and yarder productivity for the study block was 117 m³/man-day and 157 m³/day, respectively. Average yarding distance was 90 m. Falling, yarding, and loading costs were $3.24, $13.14, and $6.43/m³, respectively, for a total of $22.81/m³.

Table 4. Summary of Post-Harvest Soil Disturbance

Soil disturbance category	Area (% of block)
Mineral soil exposed by yarding	7.4
Rehabilitated road	3.5
Backspar trail	0.3
Undisturbed	78.5
Slash covered	6.6
Other (stump, rock, creek)	3.7

The productivity of hand-falling operations was found to increase with an increase in tree size. A prediction function, based on gross merchantable tree volume, estimated the productivity of falling and processing operations to be 115 and 155 m³/man-day in stands with an average tree size of 1.0 and 2.0 m³, respectively. The study recorded little stem breakage during the falling operation, and attributed it to the skill and care of fallers in directing the trees away from potentially damaging ground obstacles. Bucking the stems into log lengths at the falling site also is credited with reducing breakage of felled stems from falling trees.

The productivity of the yarding operation was found to vary with yarding distance and turn size. Turn size will vary not only with piece size, but also with the number of chokers used. Yarding operations with one chokersetter are more likely to use fewer chokers than yarding operations with two chokersetters. FERIC found a 30-50% reduction in yarding productivity and a 20-40% increase in the yarding cost (depending on yarding distance) when the operation used two chokers and one chokersetter rather than four chokers and two chokersetters. Operations in which the operator unhooks the loads (i.e. no chaser at landing) can expect 10-15% lower productivity, but the same yarding cost as operations employing a chaser. Yarding productivity was also affected by the frequency of changing skyline roads (moves) and the type of backspar used. FERIC recorded move times ranging from 5 to 63 min, with the shortest move time occurring when only the mobile backspar was moved, and the longest occurring when the rigging was moved between spar trees.

The post-harvest slash survey measured 18.1 m³/ha, of which 87% was from pieces <15 cm in diameter. Pieces <3 m in length accounted for 40% of the volume. The post-harvest soil disturbance survey found that the yarding operation disturbed 11.2% of the area to some degree, with exposed mineral soil being the most common (7.4%).

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Disclaimer

This report is published solely to disseminate information to FERIC members. It is not intended as an endorsement or approval by FERIC of any product or service to the exclusion of others that may be suitable.

APPENDIX I

Bucking Specifications

Log sort	Code	Minimum top diameter (cm)	Minimum length (m)	Preferred lengths (m)
Douglas-fir				
Lumber	L	51	5.0	16.6, 14.8, 12.6, 10.4, 8.4, 6.4
Merch	F	38	5.0	Same as for lumber
Peeler	P1	20 to 38	5.8	16.4, 13.6, 11.0, 8.4, 5.8
Gang	P2	15	11.0	Same as for P1
Saw gang	G1	20 to 38	5.0	
	G2	15	11.0	
Pulp	X	15	3.2	
Western hemlock				
Merch	M	38	5.0	16.4, 14.8, 12.6, 10.4, 8.4, 6.4
Saw gang	G1	20 to 38	5.0	Same as for Merch
	G2	15	11.0	Same as for Merch
Pulp	X	15	3.2	
Western redcedar				
Merch	M	38	5.0	12.6, 12.0, 11.4, 10.6, 10.0, 6.4, 5.8, 5.2
Saw gang	G	15 to 38	5.0	Same as for Merch
Utility	X	15	3.2	

APPENDIX II

Costing

Calculation of Machine Charge-Out Rates

	Washington SLH78 swing yarder New	Washington SLH78 swing yarder Used	Mobile backspar Used	Chapman CH172 loader
Machine cost input data				
Purchase price, P ($)	790 000[a]	150 000	125 000	350 000
Salvage value, S (% of P)	20	20	20	20
Depreciation period, D (y)	12	6	6	8
Machine utilization, MU (%)	90	80	80	95
Operating days/year (no.)	180	180	180	180
Shifts/day (no.)	1	1	1	1
SMH/shift (h)	8	8	8	8
OMH/year (h)	1 296	1 152	1 152	1 368
Average investment ($/y)	474 000	90 000	75 000	210 000
Interest on investment (%)	10	10	10	10
Insurance (%)	3	3	3	3
Fuel consumption F (L/OMH)	35	35	5	30
Fuel cost, FC ($/L)	0.45	0.45	0.45	0.45
Oil consumption (% of F)	4	4	4	4
Oil cost ($/L)	2.50	2.50	2.50	2.50
Repair cost (% of P/100 OMH)	1	6	1	1
Operating cost/OMH				
Depreciation ($)	40.64	17.36	14.47	25.58
Interest on investment ($)	36.57	7.81	6.51	15.35
Insurance ($)	10.97	2.34	1.95	4.61
Repair/maintenance ($)	79.00	90.00	12.50	35.00
Fuel cost ($)	15.75	15.75	2.25	13.50
Lubrication cost ($)	3.50	3.50	0.50	3.00
Charge-out rate[b] ($/OMH)	186.43	136.76	38.18	97.04
Charge-out rate ($/SMH)	167.79	109.41	30.54	92.19

[a] The Washington SLH78 is no longer manufactured; purchase price used in the cost analysis is based on similar types of machines marketed by S. Madill Ltd. or Ross Corporation. [b] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company involved in the study.

Labour Rates (IWA-Canada), as of June 15, 1993)

Position	Rate ($/h)
Yarding engineer	21.97
Hooktender	21.38
Chokersetter	18.61
Chaser	18.79
Loader operator	20.79