WOOD HARVESTING

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TN243

SHELTERWOOD HARVESTING WITH A SKYLINE SYSTEM IN A COASTAL SECOND-GROWTH FOREST

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Abstract

A shelterwood harvest in a Coastal second-growth forest in southwestern British Columbia was completed in late 1994 using Madill 071 and 171 yarders, rigged with standing skyline systems. The Forest Engineering Research Institute of Canada (FERIC) monitored the harvesting activities to evaluate and document productivities and costs of the harvesting phases, and to describe influencing factors.

Introduction

In 1994, the British Columbia Ministry of Forests (BCMOF), Squamish Forest District, initiated a shelterwood harvest to investigate the feasibility of non-clearcut harvesting in the District's second-growth forests. The District's forests are heavily used by Greater Vancouver residents for recreational hiking and skiing, so the visual impact of forestry operations is an important consideration in selecting appropriate harvesting methods. Other objectives of this trial were to provide the BCMOF and local contractors with operational experience and to demonstrate partial cutting techniques.

The Forest Engineering Research Institute of Canada (FERIC) monitored the harvesting operation, observed the cable yarding practices used by the contractor, and obtained productivity and cost information to describe the harvest.

Study Methods

Pre-harvest site and stand descriptions were obtained from BCMOF surveys and the Pre-harvest Silviculture Prescription prepared by Squamish Forest District. Number of residual trees and damage information were also provided by the BCMOF.

FERIC mounted Servis recorders on the harvesting equipment to determine machine operating time, and records of crew time were provided by the contractor. Intermittently throughout the period of harvest, yarding cycles were timed with stop watches to quantify individual cycle elements. The BCMOF provided the harvested volume calculated from the scale data.

Using its standard costing formula, FERIC calculated harvesting cost per cubic metre by applying 1994 IWA labour rates and hourly machine costs against the total hours for the crew and the equipment (Appendices I and II). The resulting costs were then prorated to the scaled volume for the block.

Site and Stand Description

The study site was a 15.7-ha block situated in the Ring Creek area near the town of Squamish. The site receives moderate recreational use and is classified as Partial Retention from viewpoints in both the Highway 99 corridor and Squamish (BCMOF 1981). It is within the Coastal Western Hemlock Dry Maritime ecosystem (CWHdm) (Green and Klinka 1994), and has deep soils (>100 cm), a range of 5-45% slope (averaging 30%) and a southwestern aspect. Overall sensitivity to site degradation is moderate.

The 70-year old stand consisted of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and

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western redcedar (*Thuja plicata* Donn), and had established itself naturally after harvesting. Net merchantable volume was 660 m^3/ha, with 791 trees/ha and 2 snags/ha. Tree size averaged 0.83 m^3, but varied considerably with species; Douglas-fir was the largest at 1.22 m^3/tree, while cedar and hemlock were much smaller, at 0.38 and 0.35 m^3 respectively.

Silvicultural Prescription

The BCMOF prescribed a shelterwood harvest, retaining 80-120 residual trees/ha in dominant and codominant crown classes, to meet the visual quality objectives. Leave trees were selected and marked with paint. Douglas-fir was the preferred species but western redcedar was also acceptable.

A second harvest (removal cut) is planned in 40 years, when half of the residual trees are to be harvested. The trees remaining after the second entry (40-60 trees/ha) will be left until the regeneration is harvested 60-70 years after its establishment. Both natural seeding and planting will contribute to the regeneration.

Harvesting System and Equipment

The Squamish Forest District staff worked with a consulting firm, Forest Engineering Inc. of Oregon, to design the cutblock and to learn the layout procedures and considerations for this type of harvest. The block was designed with moderate yarding distances (maximum of 240 m), and was accessed by three roads, allowing all logs to be yarded uphill. Yarding corridors were located at 40-60 m intervals with corridors, backspar trees and leave trees marked prior to falling.

The harvesting contract was competitively awarded through the Small Business Forest Enterprise Program to GBA Logging Ltd. of Squamish. The company had experience in partial cutting, primarily harvesting on private land to develop recreational trails and sites.

Harvesting began in late September 1994 and was completed by early December. The less experienced fallers clear-felled the corridors, while more experienced fallers worked within the partially cut strips, directionally felling the stems towards the corridors in a slight herringbone pattern. If safety or harvesting logistics required their removal, fallers could fell marked trees provided comparable unmarked ones were substituted. Delimbing and bucking were done concurrent with the falling phase.

For a period of two weeks prior to yarding, a Madill 3800 hydraulic log loader retrieved logs within reach of the road (cherry-picked) and loaded them onto highway logging trucks. A Madill 071, rigged as a standing skyline and with a Danebo mechanical slackpulling dropline carriage, began yarding October 12, 1994 (Figure 1). Later, when it became clear the operation would not be completed before seasonal rains made the roads impassable, a Madill 171 with a Johnson SPC092C dropline carriage, was added. This yarder was also rigged with a standing skyline system and was supported by a Hitachi EX300 hydraulic log loader. The specifications for the yarders are identified in Table 1.

The hooktender and an assistant pre-rigged each backspar with skyline and haulback blocks hung from short

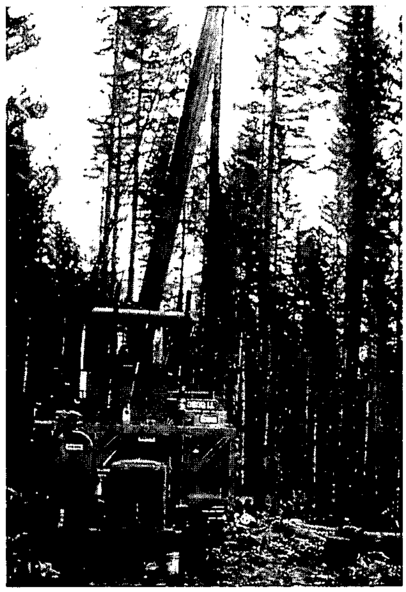

Figure 1. Madill 071 yarder.

Table 1. Specifications for the Madill 071 and 171

	Madill 071 mobile yarder	Madill 171 mobile yarder
Maximum power (kW)	212	336
Tower height (m)	14.3	15.4-21.4[a]
Total weight (kg)	38 800	46 400
Winch drums (no.)	5	5
Guylines (no.)	3	4
Mainline		
Maximum line pull (kg)	25 600	32 600
Maximum line speed (m/min)	529	577
Skyline		
Maximum drum capacity (25 mm line) (m)	590	590

[a] The Madill 171 tower can be extended hydraulically. However, this capability was used on only one corridor within the study area.

choker straps on the tree. Four backspar guylines were set, tensioned with a come-along, and secured with crosby clamps. A stump or tree, in lead with the backspar and yarder, was selected as a skyline anchor and then notched, rigged with a strap, and tied back with twisters.

In preparation for changing yarding corridors, strawline extensions were strung through the blocks mounted on the backspar of the new corridor and back to the active backspar, and from the yarder along the next corridor to the new backspar. When a corridor change was made, the yarder was usually back in production within 45 minutes. The haulback line was strung along the previously-yarded corridor to minimize the exposure of the crew to running lines while they worked on both sides of the skyline. Figures 2 and 3 illustrate the rigging arrangement used for this harvest. Rigging a backspar usually took 5 hours, so the hooktender's assistant spent the remainder of the shift setting chokers. However, when both yarders were operating, backspar rigging and stripping (removing the rigging from the backspar when yarding on a corridor was finished) were full-time activities.

A rigging slinger and chokersetter worked within the block. All logs accessed by a corridor were yarded in one setup. Logs directly under the skyline were yarded first and then the logs on either side of the corridor were extracted in an alternating pattern. The alternating pattern allowed chokers to be preset when longer yarding distances were encountered or when an additional chokersetter was available.

A landing person unhooked the chokers at roadside, bucked long logs and broken ends, trimmed limbs, marked logs, and assisted the loader operator when necessary.

The BCMOF hired a contract supervisor to visit the site daily during the early stages of the trial and as required for the remainder of the operation. This close supervision gave the harvesting crew good feedback about unacceptable types and levels of residual tree damage, and exchanges of residual trees when necessary for falling or yarding safety or efficiency.

Results

Productivity and cost

A total net volume of 9 814 m^3 was removed from the block, including cable-yarded wood and the volume that was retrieved near the roadside by the Madill log loader. For the road development and yarding distances in this block, the harvesting contractor estimated that 5% of the volume was cherry-picked with the loader,[1] so the yarders harvested an estimated 9 323 m^3. However, volumes could not be separated for the two yarders.

[1] Greg Richmond, GBA Logging Ltd., Squamish, B.C.; personal communication, July 6, 1995.

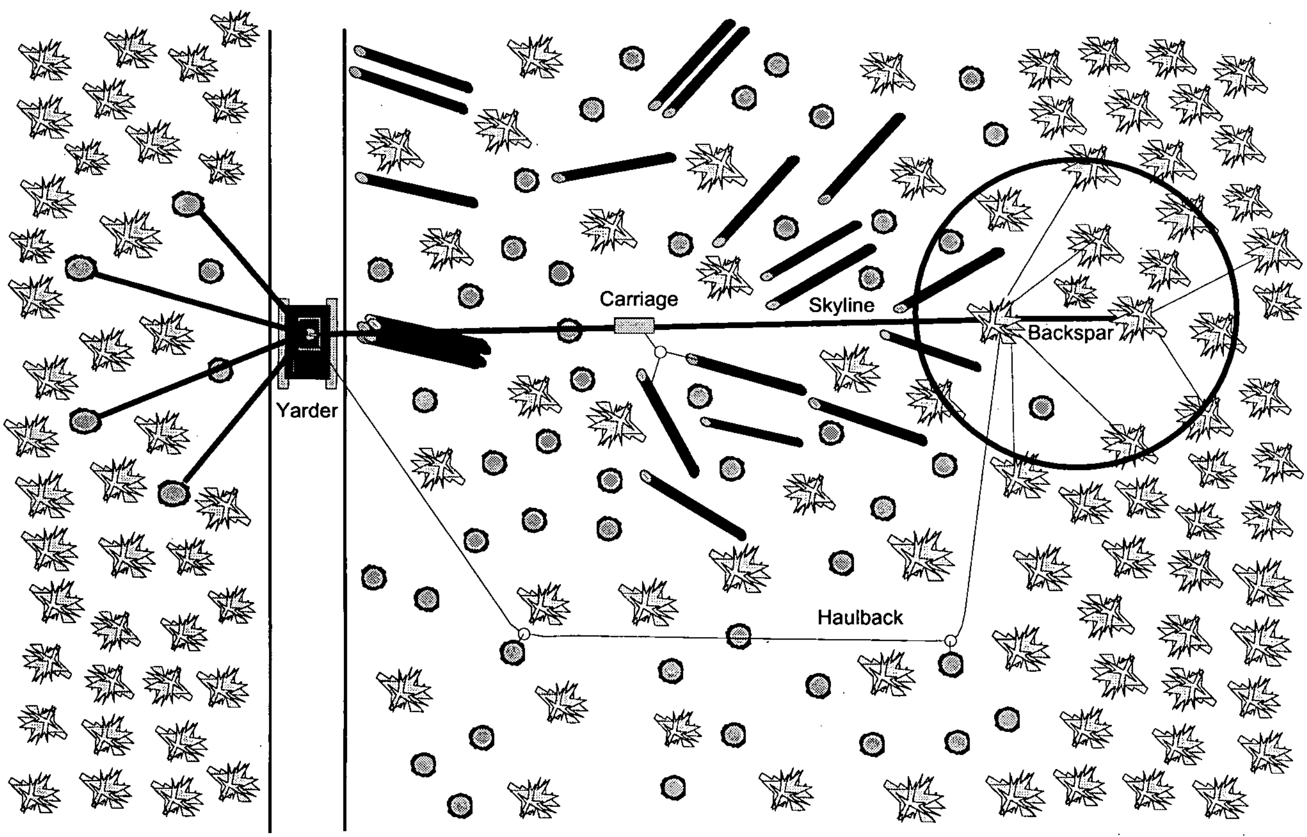

Figure 2. Typical standing skyline arrangement used in the study.

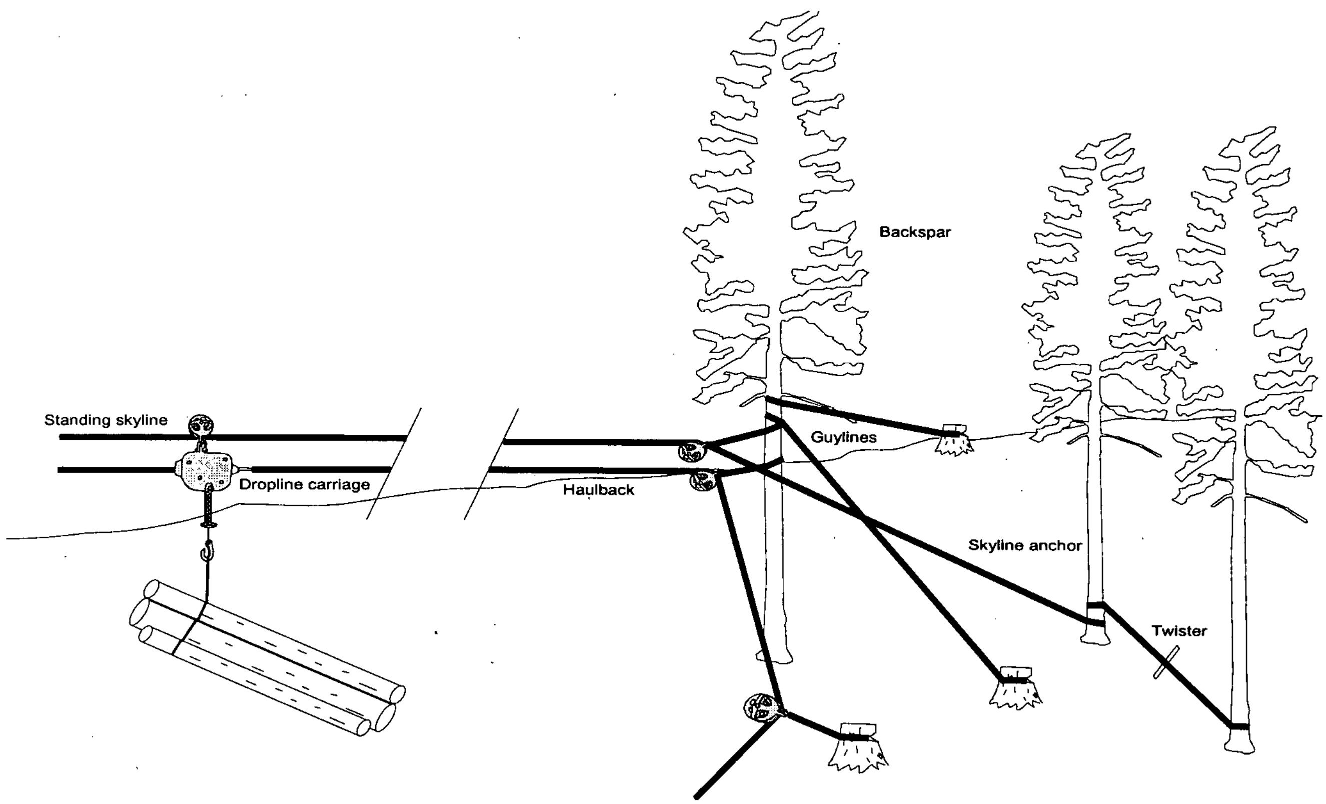

Figure 3. Typical backspar rigging arrangement used in this study. (Only two of the four guyline stumps are shown.)

A total of 147 faller-days was required, yielding a falling productivity of 67 m^3/shift. Falling cost, at the IWA day-rate with 35% benefits and \$27/day allowance for chain saws, was \$5.88/m^3. One portion of the block, consisting of small, dense western hemlock without acceptable leave trees, was clear-felled; falling productivity in this area was not separated but was considered to be low. Quality of falling in the partially cut area appeared to be high as few incidents of misaligned stems were observed during yarding.

Table 2 presents the results of the detailed timing of the yarding cycles. Although with the Madill 171 the number of pieces/cycle was slightly greater, the average time/piece was almost identical to that of the Madill 071. The Madill 171 is more powerful than the 071 and therefore is better suited to long yarding distances. In this operation, however, yarding distance was relatively short and the greater capacity of the 171 could not be realized. Inhaul time was greater for the Madill 171 than the 071, despite a shorter average yarding distance, but there was no obvious explanation for this result.

Tables 3 and 4 summarize the productivity and cost of the harvesting operation. Overall yarding productivity for the two yarders was 186 m^3/shift. Shift level results showed the yarders performed their primary function for 7.51 h/shift, based on a shift length of 9 h. Changing corridors accounted for 8.6% of the shift time, and 0.10 h for every hour of actual yarding.

Fifty man-days were attributed to rigging, based on the contractor's estimate that 5 h with a 2-person crew were required for each corridor, to rig the backspar tree and to pull strawline in preparation for the yarding road change. This yields a rigging cost of \$1.65/m^3, based on the total net volume removed from the cutblock.

The cost of yarding and loading is calculated as \$21.11/m^3 (excluding backspar rigging). The loaders operated on some weekends and both before and after yarding was completed. A total of 81 loader-days was worked compared to 50 yarder-days. This relationship may be out of balance in part because extra equipment was brought to ensure the harvesting was completed before snowfall.

Overall, the total cost on the truck was estimated to be \$28.64/m^3.

In order to meet the demonstration objective of the study, during the harvesting, the BCMOF, GBA Logging Ltd. and FERIC hosted tours of the operation. The FERIC tour in November 1994 included forest industry, university and contractor representatives.

Table 2. Distribution of Yarding Cycle Time

	Average time per element								
	Outhaul (min)	Hook-up (min)	Inhaul (min)	Unhook (min)	Delay (min)	Total cycle (min)	Average yarding distance (m)	Average pieces (no./cycle)	Samples (no.)
Madill 071	0.59	1.67	0.85	0.49	0.07	3.67	83	2.9	237
Madill 171	0.46	2.18	1.15	0.69	0.15	4.63	69	3.6	89

Table 3. Summary of Productivity

Production	
Total (m^3)	9 814
Yarder (m^3)	9 323
Shifts	
Fallers (no.)	147
Yarders (no.)	50
Productivity	
Falling (m^3/shift)	67
Yarding (m^3/shift)	186
(pieces/shift)	297
Distribution of yarding time[a]	
Yarding (h/shift)	7.51
Changing corridors (h/shift)	0.77
Delays (h/shift)[b]	0.46
Warm-up, maintenance (h/shift)	0.26
Total (h/shift)	9.00

[a] Combining both the Madill 071 and 171. [b] Delays were almost exclusively mechanical, primarily repair to the rigging. Several days with early shut-down due to wind are excluded here.

Table 4. Harvesting Costs: Summary

Description	Shifts (no.)	Costs ($)	Costs ($/m³)
Falling labour	147	53 732	
Chain saws	147	3 969	
Loaders - Madill 3800	55	46 497	
Hitachi EX300	26	23 686	
Yarders - Madill 071	33	24 030	
Madill 171	17	20 279	
Yarding and loading labour	281	91 307	
Chain saws	50	1 350	
Backspar rigging labour	50	16 173	
Falling			5.88
Yarding and loading			21.11
Backspar rigging			1.65
Total on the truck			28.64

Residual stand

The BCMOF conducted post-harvest surveys to determine numbers of, and damage to, residual trees.[2] An average of 90 trees/ha remained (excluding the area of pure hemlock which was clearcut), meeting the prescription. Damage to residual trees was concentrated along the yarding corridors and along the roads. An estimated 7.5% of the residual trees were damaged, with 1.6% of the trees damaged with a severity judged unacceptable. By January 1996, 14 months after felling was completed, two residual trees had blown down.[3]

Discussion

The contractor's experience in partial cutting was evident in the work organization of the crews. There were no delays relating to sequencing of activities: logs were always available for yarding, the next corridor was pre-rigged, and the loaders had logs available to load onto trucks. The trucks experienced some delays associated with poor road conditions resulting from heavy rain. The operation was also expedited by the BCMOF supervisor on-site, who ensured that the residual-tree requirements were met and that minor adjustments to the logging plan were immediately addressed.

In 1993, FERIC studied another partial cutting operation in Douglas-fir with a similar prescription, at Roberts Creek on the southwestern coast of British Columbia (Hedin 1994) (Table 5). The stand at Ring Creek, however, was younger with lower volume and smaller trees, and was located on a steeper site.

Faller productivity was substantially lower at Ring Creek compared to the Roberts Creek study site (67 m^3 compared to 150 m^3/shift). This was attributed mainly to the smaller tree size (0.83 m^3/tree at Ring Creek compared to 1.7 m^3/tree at Roberts Creek).

[2] Mike Wallace and Keith Magee, BCMOF, Squamish Forest District, Squamish, B.C.; personal communication, August 29, 1995.

[3] Mike Wallace, BCMOF, Squamish Forest District, Squamish, B.C.; personal communication, January 1996.

Table 5. Comparison of Results for FERIC Studies at Roberts Creek and Ring Creek

	Roberts Creek (1993)	Ring Creek (1994)
Harvesting equipment	Cypress 6280B swing yarder	Madill 071 and 171
Stand description		
Preharvest (trees/ha)	670	791
Preharvest (m^3/ha)	1136	600
Average tree size (m^3)	1.7	0.83
Post-harvest (trees/ha)	57	90
Falling		
Productivity (m^3/shift)	150	67
Yarding		
Shift length (h)	8	9
Productivity (m^3/shift)	205	186
Producitvity (pieces/shift)	221	297
Average time (min/cycle)	6.36	3.93
Productivity (pieces/cycle)	4.1	2.9
Cost on the truck (\$/m^3)	18.12	28.64

The effect of tree size was evident in subsequent phases as well. At Ring Creek, there did not appear to be any disadvantage to falling all trees within and adjacent to a corridor in a single pass before yarding. However, at Roberts Creek the trees within the corridor were felled and extracted first, and then trees adjacent to the corridor were felled and yarded. The larger and taller trees at Roberts Creek had a greater risk of stem and log breakage during falling, so the multiple entry method used by the contractor likely improved recovery.

Piece size, and therefore turn volume, also had a considerable impact on yarder productivity for the two studies. At Roberts Creek, a Cypress 6280B swing yarder was rigged as a running skyline system and the carriage was adapted from a grapple carriage. Yarding productivity at Roberts Creek was 205 m^3/8-h shift, compared to 186 m^3/9-h shift at Ring Creek. The Madill 071 at Ring Creek averaged 297 pieces/shift, with an average of 2.9 pieces/cycle, compared to 221 pieces/shift and 4.1 pieces/cycle at Roberts Creek. Although cycle times at Ring Creek were shorter than at Roberts Creek, the lower number of pieces per cycle and smaller piece size at Ring Creek resulted in lower cycle volume and productivity. The yarding pattern at Roberts Creek required setting up on each corridor three times which increased the time needed for yarder moves. For each hour of actual yarding, 0.16 h of corridor change was required at Roberts Creek, compared to 0.10 h at Ring Creek. When hooking time/piece is compared between the Cypress 6280B and the Madills, 30% more time was used at Roberts Creek, reflecting the difference between the simple carriage arrangement used on the Cypress machine and the more efficient dropline carriages used at Ring Creek.

The total cost of logs loaded onto the truck was \$18.12/m^3 (1993) at Roberts Creek and \$28.64/m^3 (1994) at Ring Creek; much of this difference was attributable to the differences in tree size. In fact, because the yarder used at Roberts Creek was more expensive to own and operate than the Madill yarders used at Ring Creek, the effect of tree size on harvesting cost may be somewhat understated.

Conclusion

A second-growth Douglas-fir stand was harvested near Squamish using a shelterwood system to meet visual quality objectives. The area was developed by the British Columbia Ministry of Forests and the harvesting contract was competitively awarded to GBA Logging Ltd. through the Small Business Forest Enterprise Program. A Madill 071 and a Madill 171, both rigged with standing skyline systems and using backspar trees, were used for the harvest. The stand consisted of 791 trees/ha, with an average net tree size of 0.83 m^3 and a net volume of 660 m^3/ha. The prescription for residual tree density was met with 90 trees/ha left on site and a stem damage occurrence of 7.5%.

Falling productivity was 67 m^3/shift, at a cost of \$5.88/m^3. Yarding productivity was 186 m^3/shift. Yarding and loading costs were estimated at \$22.76/m^3, including \$1.65/ m^3 for pre-rigging backspars. Total cost on the truck was estimated at \$28.64/ m^3, based on FERIC's standard costing formula.

References

British Columbia Ministry of Forests. 1981. *Forest Landscape Handbook.* British Columbia Ministry of Forests, Victoria. 100pp.

Green, R.N., Klinka, K. 1994. *A Field Guide for Site Identification and Interpretation for the Vancouver Forest Region.* British Columbia Ministry of Forests, Victoria. Land Management Handbook 28. 285pp.

Hedin, I.B. 1994. *Shelterwood Harvesting in Coastal Second-Growth Douglas-Fir.* FERIC, Vancouver. Technical Note TN-216. 10pp.

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Disclaimer

APPENDIX I

Labour Cost

Crew	Rate ($/h)[a]	Shift (h/day)	Shifts (no.)	Cost ($)
Yarder operator	21.67	10	50	16 090
Loader operator	21.67	11	81	29 620
Landing bucker	20.31	10	50	15 080
Chokersetter	19.43	10	50	14 427
Rigging slinger	21.67	10	50	16 090
Faller	33.845	8	147	53 732
Saw allowance				
faller			147	3 969
landing bucker			50	1 350
Backspar rigging				
Hooktender	24.135	10	25	8 960
Assistant	19.43	10	25	7 213
Total labour cost				166 531

[a] The hourly rate is the IWA July 15, 1994 rate. To calculate cost, overtime (>8 h) is calculated at 1.5 times the rate and 35% fringe benefits are added.

APPENDIX II

Machine Cost

	Madill 071 yarder (used)[a]	Madill 171 yarder (new)	Madill 3800 log loader	Hitachi EX300 log loader
OWNERSHIP COSTS				
Total purchase price (P) $	141 744	625 516	435 000	459 120
Expected life (Y) y	6	12	10	10
Expected life (H) h	8 640	17 280	14 400	14 400
Scheduled hours/year (h)=(H/Y) h	1 440	1 440	1 440	1 440
Salvage value as % of P (s) %	20	30	30	20
Interest rate (Int) %	8.0	8.0	8.0	8.0
Insurance rate (Ins) %	1.5	1.5	1.5	1.5
Salvage value (S)=((P•s/100) $	28 349	187 655	130 500	91 824
Average investment (AVI)=((P+S)/2) $	85 046	406 585	282 750	275 472
Loss in resale value ((P-S)/H) $/h	13.12	25.34	21.15	25.51
Interest ((Int•AVI)/h) $/h	4.72	22.59	15.71	15.30
Insurance ((Int•AVI)/h) $/h	0.89	4.24	2.95	2.87
Total ownership costs (OW) $/h	18.73	52.17	39.81	43.68
OPERATING COSTS				
Wire rope (wc) $	28 000	28 000		
Wire rope life (wh) h	1 800	1 800		
Rigging & radio (rc) $	10 318	10 318		
Rigging & radio life (rh) h	5 700	5 700		
Fuel consumption (F) L/h	26.0	41.0	25.0	27.0
Fuel (fc) $/L	0.45	0.45	0.45	0.45
Lube & oil as % of fuel (fp) %	10	10	10	10
Track & undercarriage replacement (Tc) $	20 000	22 000	22 000	22 000
Track & undercarriage life (Th) h	6 000	6 000	6 000	6 000
Annual operating supplies (Oc) $[b]	16 200	16 200		
Annual repair & maintenance (Rp) $	25 000	40 000	41 300	43 750
Shift length (sl) h	9.0	9.0	10.0	10.0
Wire rope (wc/wh) $/h	15.56	15.56		
Rigging & radio (rc/rh) $/h	1.81	1.81		
Fuel (F•fc) $/h	11.70	18.45	11.25	12.15
Lube & oil ((fp/100)(•F•fc)) $/h	1.17	1.85	1.13	1.22
Track & undercarriage (Tc/Th) $/h	3.33	3.67	3.67	3.67
Operating supplies (Oc/h) $/h	11.25	11.25		
Repair & maintenance (Rp/h) $/h	17.36	27.78	28.68	30.38
Total operating costs (OP) $/h	62.18	80.37	44.73	47.42
TOTAL OWNERSHIP AND OPERATING COSTS[c]				
(OW+OP) $/h	80.91	132.54	84.54	91.10

[a] The Madill 071 is no longer manufactured. Prices of used yarders vary with their conditions.

[b] Operating supply costs for the yarders are primarily choker requirements.

[c] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, overhead or transportation, and are not the actual costs for the contractor or company studied. Labour is calculated separately in this study.