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## Contents



# Skyline partial cutting in the Interior Cedar-Hemlock biogeoclimatic zone: harvesting productivity and cost

**Abstract**

In 1999, the Forest Engineering Research Institute of Canada (FERIC) studied a group selection partial cutting operation in an Interior Cedar-Hemlock (ICH) stand, about 90 km north of Revelstoke, B.C. A Madill 071 multi-drum cable yarder harvested the site using northbend, gravity skyline (shotgun), and running/scab skyline configurations. The study objective was to evaluate the economics and operational feasibility of using skyline yarding systems for partial cutting in the ICH biogeoclimatic zone. This report describes the results of this case study.

**Keywords**

Partial cutting systems, Group selection harvesting, Cable logging, Skyline, Madill 071 multi-drum cable yarder, Interior Cedar-Hemlock biogeoclimatic zone, Productivity, Costs, Interior British Columbia.

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## Introduction

Forest management practices in B.C. are changing rapidly to better accommodate the management of non-timber resources. Partial cutting is gaining broad acceptance as a means of addressing a variety of non-timber objectives. In 1997/98, approximately 55% of the harvest from public forest land was obtained by some method of partial cutting or commercial thinning (BCMOF 1999).

Operational trials can help the forest industry develop efficient partial cutting practices in ecosystems where experience with partial cutting is still limited. For example, the ICH biogeoclimatic zone is a significant component of the forest land base in interior B.C. but presently is not well represented in the partial cutting literature. To address this knowledge gap, FERIC initiated a project in 1996 to study partial cutting with cable systems in the ICH zone. The first case study in this project examined a small cable yarder working in a group selection prescription near Kitwanga, B.C. (Pavel 1999).

This report documents the second case study in this project. It describes a partial cutting treatment designed to maintain ungulate winter range in the Columbia Forest District, north of Revelstoke, B.C. The partial cutting operation used both ground skidding and cable yarding operations to harvest the first of three proposed entries under this system. For the purpose of this project, only the cable yarding operation was studied. FERIC worked with Revelstoke Community Forest Corporation (RCFC) and Schiller Contracting Ltd. of Revelstoke, B.C. to monitor the group selection skyline yarding operation.

This project was funded by Forest Renewal BC and addresses one of its strategic investment priorities under its Land and Resource research program—partial cutting. This study contributes information to the forest industry in its continuing effort to develop economically feasible and biologically acceptable harvesting practices for partial cutting prescriptions for the full range of site and stand conditions in B.C.

## Objectives

The goal of this project was to evaluate the economic and operational feasibility of using skyline yarding systems for partial cutting in the ICH biogeoclimatic zone. The following specific objectives were set for this case study:

- Determine overall productivities and costs for the falling, yarding and loading phases of a cable partial cutting operation.
- Analyze the effect of external yarding distance on yarding productivity for both uphill and downhill skyline yarding with this system.
- Develop production functions to relate yarding phase productivity to slope yarding distance.
- Identify and discuss other operational factors that influence harvesting performance and suggest improvements where appropriate.

## Site description

The study site was located approximately 90 km north of Revelstoke in the RCFC's Tree Farm License, on the south side of the Goldstream River Valley (Figure 1). The study area is within the very wet cool subzone (Mica variant) (ICHvk1) of the ICH biogeoclimatic zone (Braumandl and Curran 1992). Elevation is from 875 to 1100 m and topography is moderately steep with ground slopes in both the cable and ground-based units ranging from 40 to 55%. Forest cover is age class 8 (141–250 years) and height class 4 (28.5–37.4 m), and consists of western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), hybrid spruce (*Picea glauca* × *engelmannii*) and subalpine fir (*Abies lasiocarpa*). Average stand density is 267 trees/ha and average net merchantable volume is 441 $m^3$/ha (Table 1).

## Silviculture prescription

The silviculture prescription called for a group selection system to ensure important habitat was maintained for caribou, moose, bears and various cavity-nesting birds. The group selection silvicultural system proposed three entries at 30-year intervals to be followed by future entries to harvest the regenerated stands as they approach 90 years of age.

The forest growth objective is to produce a healthy uneven-aged stand of sawlog-quality hybrid spruce, western red cedar, and western hemlock. Harvested units are to be planted one to two years after harvest with hybrid spruce (50%) and western red cedar (50%) to a target density of 1400 trees/ha. Natural ingress of western red cedar and western hemlock is expected to increase the maximum density at the free-growing stage to 1600 trees/ha.

The study area was approximately 131.9 ha of which 10.1 ha were cable yarded, 19.9 ha were ground skidded,

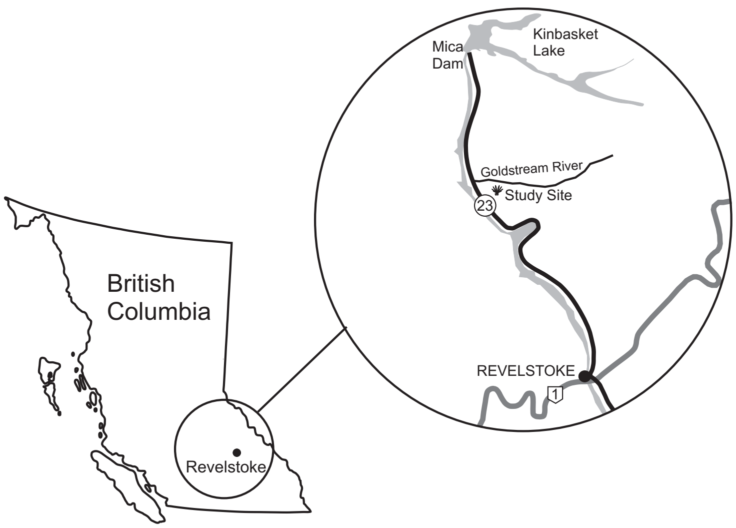


Figure 1. Location of study site.


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| Table 1. Site and stand descriptions | |
|---|---|
| Roads and landings (ha) | 4.5 |
| Reserves (ha) | 11.6 |
| Total area available for harvest (ha) [a] | 115.8 |
| Total area under prescription (ha) | 131.9 |
| | |
| First entry | |
| Cable yarding (ha) | 10.1 |
| Ground skidding (ha) | 19.9 |
| | |
| Slope of cable units | |
| Range (%) | 40–55 |
| Average (%) | 45 |
| | |
| Soils | |
| Texture | silty loam |
| Coarse fragment content (%) | 25 |
| | |
| Species composition [b] | |
| Western red cedar (%) | 67 |
| Western hemlock (%) | 30 |
| Hybrid spruce (%) | 2 |
| Subalpine fir (%) | 1 |
| | |
| Net merchantable volume/ha ($m^3$) [b] | 441 |
| Trees/ha (no.) | 267 |
| Avg dbh of live trees (cm) | 63.8 |
| Avg net merchantable volume/tree ($m^3$) | 1.65 |

[a] The study area included only 7 ha of the total cable yarding area.
[b] From operational cruise summary.

11.6 ha were in wildlife reserves, 4.5 ha were proposed or existing roads or landings, and the remaining 85.8 ha were retained for future harvesting passes. The cable portion of this harvest consisted of 11 small openings varying in size from 0.4 ha to 1.5 ha (Figure 2). Winter harvesting was prescribed for the ground skidding units. However, no seasonal restriction on harvesting was applied to the cable yarding units.

## Harvesting systems and equipment

Schiller Contracting Ltd. of Revelstoke, B.C. harvested seven of the eleven cable harvesting units and was responsible for all falling, yarding and loading activities. Falling, yarding and loading crews were experienced with conventional cable yarding and ground skidding, and had some previous experience with group-selection cable operations prior to the study.

### Falling

The falling crew consisted of a handfaller and an assistant. The assistant was responsible for pre-falling preparation, primarily shovelling snow from around the bole of the trees to give the faller access at or near the specified stump height. Generally,

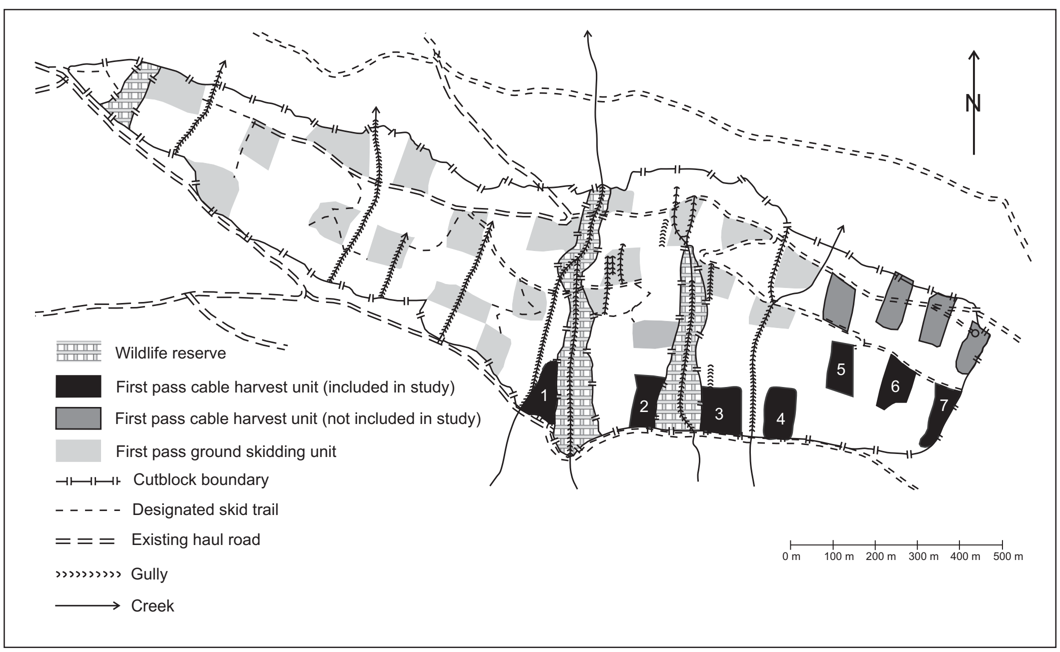


Figure 2. Cutblock map.

the faller felled the trees perpendicular to the main haul road with log butts ahead, and left stems tree length and unlimbed. Log processing and bucking were carried out at the landing during the yarding phase.

The falling schedule was determined by yarding progression. Generally, the falling crew worked ahead of the yarding crew by one treatment unit to ensure that snow on felled timber was limited to only one or two days' accumulation.

### Yarding and loading

A Madill 071 multi-drum cable yarder equipped with either butt rigging or a custom shotgun carriage performed yarding activites using northbend, gravity skyline (shotgun), and running/scab skyline configurations (Figure 3). Log clearing, decking and loading were performed with a John Deere 892D-LC hydraulic log loader. In addition, a Dresser TD-15C crawler tractor cleared logs when the log loader was unavailable. The yarding crew consisted of a yarder engineer, chaser, hooktender, rigging slinger, and chokersetter. The loading crew consisted of a loader operator and landing bucker.

Figure 3. Madill 071 multi-drum yarder equipped with butt rigging.

Both uphill and downhill yarding were performed in the study block. Several yarding systems were utilized to accommodate terrain conditions and deflection requirements and to maximize yarding productivity (Table 2). All yarding systems were rigged at stump height because most back-end trees had high rot content or were poorly rooted. Uphill yarding using a shotgun system was preferred. The northbend system was only used when terrain and deflection conditions made a shotgun system unfeasible (Figures 4 and 5). A running/scab skyline system was used on all downhill yarding units except on parts of two yarding roads in Unit 7, where the scab block was removed and the yarder was configured as a high-lead system (Figure 6).

Most yarding roads were rigged at square lead (right angles to the machine) to accommodate the predominantly rectangular shapes of the treatment units. All yarding road changes were pre-rigged by the hooktender. Because treatment units were relatively small in size, the yarder did not need to be repositioned for most yarding road changes. In general, yarding roads were typically 6–10 m wide (3–5 m on each side of the skyline) and wider if chokersetters used tags.[1] The northbend system permitted much wider yarding roads.

[1] Tag is defined as the joining of two or more chokers end to end for extended reach (Tataryn 1993).

**Table 2. Rigging configurations used in the cable units**

| Method | Treatment unit | Maximum yarding distance (m) |
|---|---|---|
| Single-span uphill yarding configured as a live skyline northbend system | 2 | 160 |
| Single-span uphill yarding configured as a live skyline shotgun system | 1, 3, 4 | 190 |
| Single-span downhill yarding configured as a running/scab skyline system | 5, 6, 7 | 190 |

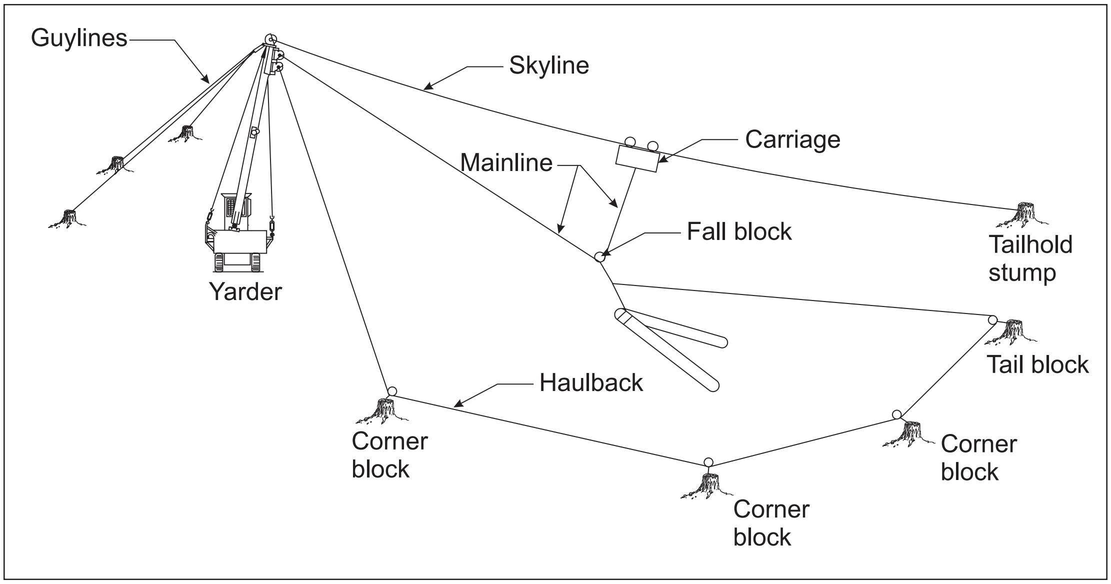


Figure 4. Northbend rigging configuration.

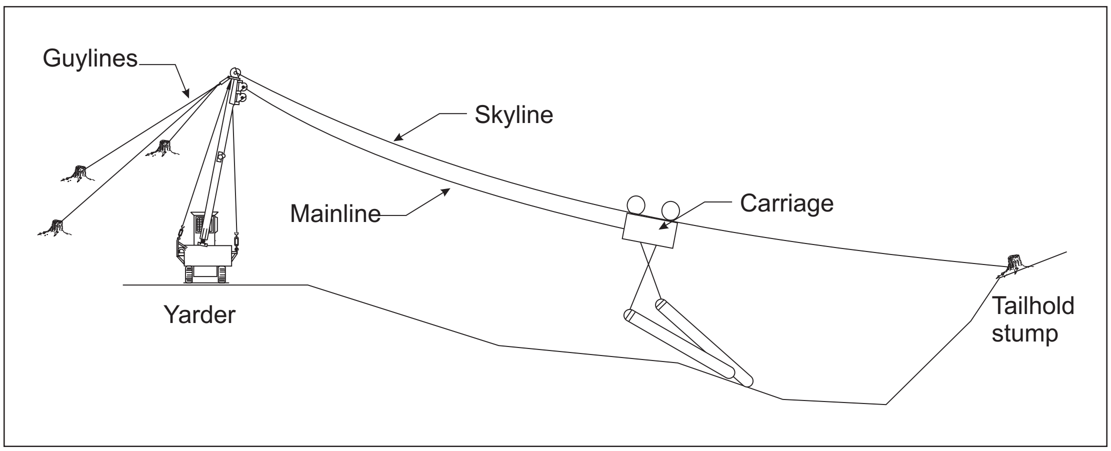


Figure 5. Shotgun system configuration.

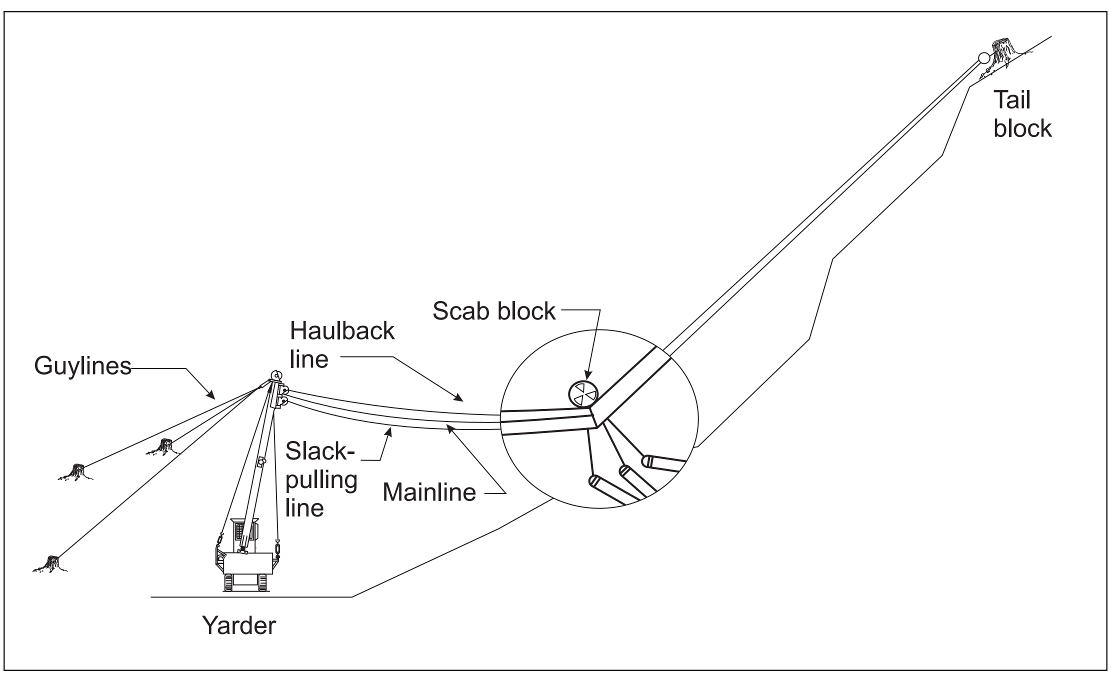


Figure 6. Running/scab skyline system configuration.

## Study methods

Harvesting productivities and costs were determined using shift-level and detailed-timing study methods. Shift-level time information was collected for the falling, yarding and loading phases. FERIC researchers performed detailed timing of yarding cycles throughout the harvesting operation and recorded information on factors affecting system productivity. Harvest volume was supplied by RCFC. Hourly machine costs were calculated using FERIC's standard machine costing methodology (Appendix I) and 1998 Industrial Wood and Allied Workers of Canada (IWA) labour rates (Appendix II).

Four group-selection units, representing both uphill and downhill yarding, were selected for detailed timing using a hand-held datalogger and electronic stopwatches. Yarding cycles were subdivided into five cycle elements: outhaul, hook-up, inhaul, unhook, and in-cycle delays. Four parameters were recorded for each timed cycle: slope yarding distance, number of chokers used, number of chokersetters, and number of logs yarded per cycle.

Linear regression equations were developed to relate outhaul and inhaul times to slope yarding distance so that average turn times could be expressed and compared for common yarding distances. The dependent variables were inhaul and outhaul times and the independent variable was slope yarding distance. A significance level of .05 was used to test the relationships and the contribution each term made to the model.

## Results and discussion

Manual falling began in early January, 1999 and was completed in mid-February with a short interruption in mid- to late January. Yarding and loading activities also began in early January and were completed by mid-February. Due to an anticipated early spring break-up, four cable treatment units were harvested by a second contractor and were not included as part of the study.

### Falling

Table 3 summarizes the falling productivity for the seven cable yarding units studied.

During 91.8 h, including in-shift idle time, 3131 $m^3$ of timber was felled. Generally, the faller and assistant worked as a team, working 3–7 hours per shift and averaging 222 $m^3$/6.5-h shift. Falling was fairly continuous with only periodic interruptions to the falling schedule, caused by yarding delays or when heavy snow loading in the stand's canopy created dangerous falling conditions.

**Table 3. Summary of falling productivity for treatment units studied**

| | |
|---|---|
| Time with falling production (h) | 91.8 |
| Shifts with falling production (no.) | 15 |
| Average shift length (h/shift) [a] | 6.1 |
| Average falling time/ha (h) [b] | 13.1 |
| Volume felled ($m^3$) [c] | 3131 |
| Trees felled (no.) | 1898 |
| Volume/tree ($m^3$) [d] | 1.65 |
| Average volume felled/6.5-h shift ($m^3$) | 222 |
| Average trees felled/6.5-h shift (no.) | 134.5 |

[a] Falling shift length ranged from 3 to 7 h.
[b] Gross area harvested as part of the study area is 7 ha.
[c] Assumed to be equal to volume obtained from scale reports.
[d] The average obtained from the operational cruise summary.

Falling productivity was adversely affected by frequent and heavy snowfalls. The falling crew often had to work in snow deeper than 1.6 m and stated that the deep snow increased their walk, preparation, and snow removal times. Heavy snow loading in the stand's canopy created a safety hazard and some lost shifts. Additionally, the falling phase was no more than two days ahead of yarding to avoid burying logs in heavy snowfalls, which resulted in complete or partial losses to falling shifts when significant delays occurred in the yarding phase.

### Yarding and loading: shift-level

Table 4 summarizes the shift-level data for the yarding and loading phases.

**Table 4. Summary of yarding and loading productivities by yarding direction**

| | Uphill yarding | Downhill yarding | Combined |
|---|---|---|---|
| Yarder | | | |
| Shifts with yarding production (no.) | 13 | 6 | 19 |
| Time with yarding production (h) | 66.5 | 37.9 | 104.4 |
| Time spent changing yarding roads (h) | 10.1 | 3.3 | 13.4 |
| Time spent moving between units (h) | 6.5 | 3.0 | 9.5 |
| Time spent servicing yarder (h) | 2.0 | 1.2 | 3.2 |
| Total time (h) | 85.1 | 45.4 | 130.5 |
| Yarding productivtiy | | | |
| Volume yarded ($m^3$) | 1 928 | 1 203 | 3 131 |
| Cycles yarded (no.) | 710 | 419 | 1 129 |
| Average cycles/8-h shift (no.) | 67 | 74 | 69 |
| Average volume/cycle ($m^3$) | 2.7 | 2.9 | 2.8 |
| Average volume yarded/8-h shift ($m^3$) [a] | 182 | 212 | 192 |
| Road changes | | | |
| Road changes (no.) | 38 | 23 | 61 |
| Average time/road change (h) | 0.27 | 0.14 | 0.22 |
| Average volume yarded/road change ($m^3$) | 51 | 52 | 51 |
| Time with loader production (h) [b] | 108.1 | 63.1 | 171.2 |
| Log truck loads (no.) | 49 | 31 | 80 |
| Average volume/load ($m^3$) | 39.3 | 38.8 | 39.1 |

[a] Differences due to rounding.

[b] The crawler tractor cleared log decks for a total of 6.5 h when the loader was loading trucks or mechanically unavailable.

Nineteen yarding shifts averaging 6.9 h/shift were spent in the study area, with 85.1 scheduled machine hours (SMH) in the uphill yarding units and 45.4 SMH in the downhill yarding units. Overall, 80% of yarding shift time was spent performing yarding functions (Figure 7).

The yarding crew averaged 69 turns or 192 $m^3$ per shift and 2.8 $m^3$/turn. In total, 61 yarding road changes were performed, averaging 0.22 h/yarding road change and 51 $m^3$/yarding road. Generally, the downhill yarding units achieved better production per shift than the uphill yarding units (212 $m^3$ versus 182 $m^3$, respectively). Yarding road changes required 10 to 20 min depending on the yarding system utilized. All road changes were pre-rigged by the hooktender, and required 15 to 20 min to locate the tail stumps, install the tailblocks, and string the strawline extensions. Higher productivity in downhill yarding units is mainly attributable to the difference in time spent performing yarding road changes (12% of time in uphill yarding units versus 7% of time in downhill yarding units). Snow levels were generally

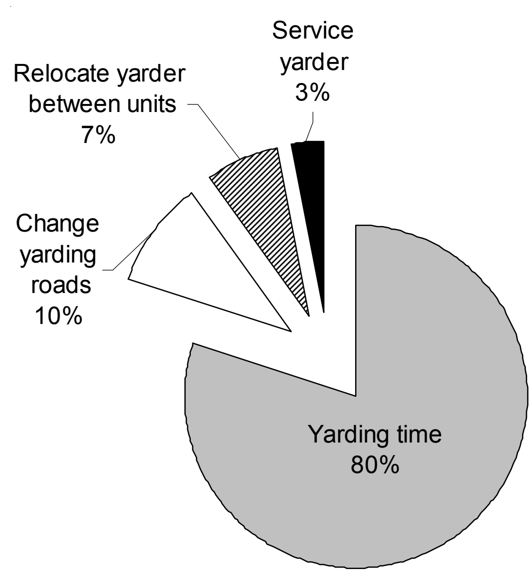


Figure 7. Distribution of yarder time.

deeper while yarding in the uphill yarding units, but most of the increase in overall road change time was the result of the complexity of rigging the northbend system.

The loader spent 171.2 SMH clearing, decking and loading wood yarded from the cable units. In addition, the crawler tractor spent 6.5 h clearing logs from the landing while the log loader was either mechanically unavailable or loading log trucks. When yarding distances were longer, the loader was often idle while waiting to assist the yarder with landing logs. This type of loader inefficiency is common to cable yarding operations where the yarder requires a dedicated loader. Boswell (1999) found that during yarding on four skyline cutblocks, the loaders spent an average of 24% of SMH idle.

### Yarding operations: detailed timing

Table 5 summarizes the detailed timing results by yarding direction and system. The downhill yarding units rigged with a running/scab skyline had the lowest average cycle time when standardized to 100 m slope distance, at 5.76 min/cycle. This was followed by the uphill yarding units rigged with a shotgun system at 5.95 min, and the uphill yarding units rigged with a northbend system at 11.35 min. Pieces/cycle varied from 1.8 to 2.4. On average, three chokersetters and two chokers were used in the uphill yarding units (one chokersetter spent most of the time shovelling snow and preparing the logs for hooking) and two chokersetters and three chokers were used in the downhill yarding units.

Long hook-up times were a result of large snowfall accumulations on top of the felled stems, which required chokersetters to shovel snow to locate and hook turns. During detailed timing on the uphill yarding units, felled stems generally were covered by 0.3 to 0.5 m of snow. However, when detailed timing on downhill yarding units was done, stems generally had little or no snow on top of them. As a result, hook-up time was 29% faster on the downhill compared with the uphill yarding units. In addition, the downhill yarding units averaged 21% more pieces/turn than the uphill yarding units.

In-cycle delays occurred with all three rigging configurations and were comprised of 10–20% of total turn time. The

**Table 5. Detailed timing summary of yarding cycle elements by yarding direction and yarding system**

| | Single-span uphill Live skyline northbend | | Single-span uphill Live skyline shotgun | | Single-span downhill Running/scab skyline | |
|---|---|---|---|---|---|---|
| | Total | (%) | Total | (%) | Total | (%) |
| Average time per element | | | | | | |
| Outhaul (min) | 0.86 | 8 | 0.30 | 5 | 0.34 | 6 |
| Hookup (min) | 4.79 | 45 | 3.23 | 57 | 2.63 | 45 |
| Inhaul (min) | 1.69 | 16 | 0.85 | 15 | 0.84 | 15 |
| Unhook (min) | 1.18 | 11 | 0.77 | 13 | 0.89 | 15 |
| Total delay-free cycle time (min) | 8.52 | 80 | 5.15 | 90 | 4.70 | 81 |
| In-cycle delays (min) | 2.13 | 20 | 0.56 | 10 | 1.10 | 19 |
| Cycle time | | | | | | |
| Total (min) | 10.65 | 100 | 5.71 | 100 | 5.80 | 100 |
| Standardized to 100 m (min) | 11.41 | - | 5.95 | - | 5.76 | - |
| Average operating conditions | | | | | | |
| Yarding distance (m) | 77 | - | 83 | - | 103 | - |
| Pieces/cycle (no.) | 1.8 | - | 2.0 | - | 2.4 | - |
| Chokersetters (no.) | 2.6 | - | 2.9 | - | 2.2 | - |
| Chokers (no.) | 2.2 | - | 2.4 | - | 3.0 | - |
| Sample cycles (no.) | 40 | - | 87 | - | 104 | - |

northbend system had the most in-cycle delay time. Most of this time was due to re-hooking turns and pulling/re-rigging tailholds. Re-hook delays, throughout the study, were primarily caused from fighting hang-ups or trying to avoid potential hang-ups during inhaul. With the running/scab skyline system, these delays were mainly attributed to rigging equipment problems (e.g., untwisting chokers, taking off and repairing the scab block, and repairing the tailhold block) and re-hooking turns. Similarly, delays with the shotgun system were primarily for re-hooking turns, waiting for the crawler tractor to clear the landing, and rigging equipment delays (e.g., untwisting and repairing chokers).

### Yarding cycle time: regression analysis

A linear regression analysis was performed to relate outhaul and inhaul times to slope yarding distance for uphill and downhill yarding. Average delay-free cycle time was generated by adding average hook-up and unhook times to the predicted outhaul and inhaul times for the respective average slope yarding distance.

Slope yarding distance was not a significant factor in determining inhaul, outhaul and overall delay-free cycle times for uphill yarding. The effects of poor weather and deep snow levels during uphill yarding overshadowed that of slope yarding distance. Therefore, the results of the regression analysis for uphill yarding are excluded from this report.

During downhill yarding, high snow levels made stumps and other obstacles difficult to see, so more time was spent starting and stopping turns to avoid and/or fight hang-ups during inhaul. Each time the turn was stopped, momentum was lost resulting in an overall slower inhaul time. Additionally, inhaul and outhaul speeds were reduced during periods of heavy snowfall and/or fog to minimize safety risks for the rigging crew.

### Harvesting costs

Table 6 summarizes the falling, yarding and loading costs for the cable yarding operation (Appendix III). The total stump-to-truck harvesting cost was estimated at $22.25/m$^3$ and is comprised of falling at $2.40/m$^3$, yarding at $12.11/m$^3$ and loading at $7.74/m$^3$.

Hourly machine costs (excluding the operator) for the yarder, loader and crawler tractor were estimated at $137.85/SMH (carriage inclusive), $83.37/SMH and $23.15/SMH, respectively (Appendix 1).

## Other observations

This study reflects many challenges typical of forest stands in the ICH biogeoclimatic zone. Forest planners prescribing cable partial cutting operations in the ICH zone should consider the operational implications of poor stand quality, steep terrain, limited log landing area, and harvesting system and season selection. The following observations from this case study could be applied to similar ICH stands in other parts of the interior.

Results of regression analysis for downhill yarding:

Outhaul (min.) = -0.013904178 + (0.003488175 × yarding distance (m))
= 0.35 min @ 103 m
n = 104 $R^2$ = 67% S.E.E. = 1.00

Inhaul (min.) = 0.301384463 + (0.005219824 × yarding distance (m))
= 0.84 min @ 103 m
n = 104 $R^2$ = 43% S.E.E. = 0.25

Delay-free cycle time = 4.71 min @ 103 m

Where: $R^2$ = Coefficient of multiple determination
S.E.E. = Standard error of the estimate

**Table 6. Summary of harvesting cost by phase [a]**

| Description | Cost ($/m³) |
|---|---|
| Falling | |
| Labour | 2.27 |
| Saw allowance | 0.13 |
| Total falling | 2.40 |
| Yarding [b] | |
| Labour | 6.37 |
| Madill 071 yarder | 5.65 |
| Shotgun carriage | 0.09 |
| Total yarding | 12.11 |
| Loading | |
| Labour | 3.06 |
| John Deere 892D-LC log loader | 4.47 |
| Dresser TD-15C crawler tractor | 0.05 |
| Saw allowance | 0.16 |
| Total loading | 7.74 |
| Total labour cost | 11.70 |
| Total machine cost | 10.55 |
| Total harvesting cost | 22.25 |

[a] Costs do not reflect opportunity costs and fixed costs incurred during weather-related shutdowns or mechanical downtime.

[b] Costs do not include yarder mobilization and demobilization.

Falling and yarding efficiencies can be affected by opening size and shape. Falling productivity in partial cutting situations can be reduced when falling in narrow openings (i.e., up to 1.5 tree lengths) because stem placement is more critical and more difficult. However, large wide openings, such as those used in the study area, provide adequate space to easily and effectively place stems. Likewise, designing small openings that maximize the amount of shift time spent yarding and the volume yarded per road change can increase yarding productivity. In this study, openings were predominantly rectangular or square, and averaged about one hectare in size, resulting in mid-range yarding distances. Other design options were limited because of lack of deflection and the inability to rig backspars or intermediate support trees due to generally high rot contents and poor rooting.

Overall, the choice of silviculture system in this study and yarding distances achieved were appropriate given the terrain type, stand conditions, and equipment complement used. A variable retention silviculture system may have been more problematic operationally because of poor stand quality, which would have increased the falling hazards and precluded the use of backspar trees or multi-span systems.

Snowfall accumulations ranged from 0.5 to 1.5 m with snow depths on top of felled timber ranging from 0 to 0.5 m. When deep snow accumulated on felled timber, chokersetters frequently had to use shovels to locate and attach chokers to stems. Harvesting the cable units in the summer rather than the winter would have eliminated snow-related delays and may have increased falling and yarding productivities. However, a summer harvest would have required the cutblock's road network to be maintained during both the winter and summer seasons because ground skidding was restricted to winter harvesting. Summer harvesting may have also increased breakage in cedar logs, because the snow would not have been available to act as a cushion during falling (Powell 1977).

The treatment units were not harvested progressively, so the yarder had to be moved back and forth along the road rather than continuously in one direction, increasing total moving time. Moving the yarder between units required 2–3 h. During most moves, the yarder was not towered down because of the short distance and gentle road gradients between units. Harvesting units in a consecutive order is especially important as between-unit distances increase and/or terrain conditions require the yarder to tower down to move.

Difficulties landing logs decreased productivity. Small landings meant logs had to be landed on the road fill bank, which was often relatively steep and caused logs to slide downslope. Yarding productivity was further reduced when the loader was unable to assist the yarder while landing logs. For example, during yarding in Unit 3, the loader broke down mid-way through the shift and the crawler tractor had to assist the yarder until the loader was repaired. During this period, unhook time and related delays increased by 60%. Using a brow log to hold logs on the sidehill until the loader or crawler tractor was able to clear them might have reduced log landing time and decreased potential hazards to the rigging crew and chaser (Figure 8). Likewise, landing size, especially in Units 3 and 4, could have been increased by installing a jump landing.[2] Because a previously harvested clearcut was located above the main haul road in Units 3 and 4, building a short spur above the haul road for the yarder would have been relatively inexpensive and logs could have been landed on the haul road. This would have prevented the logs from sliding downhill once unhooked. Although installation of jump landings would have increased site degradation, the total area disturbed would probably still have been within acceptable limits.

Downhill yarding is potentially more hazardous to the yarding crew and equipment than yarding uphill. Landings were small and yarded logs occasionally ran onto the landing during inhaul. A larger landing with the yarder positioned further away from the cutbank would have provided more space for logs to be safely landed.

A motorized slack-pulling carriage would have increased lateral yarding distance and allowed yarding turns to be preset. Increased lateral yarding distance would have decreased the number of yarding road changes and tail trees or stumps required (tail trees were difficult and time-consuming to find because most back-end trees were not sound). Presetting turns may have decreased the average turn time and provided chokersetters with more time to locate and set turns with better payloads. Although the northbend yarding system (in Unit 2) had lateral yarding capabilities, rigging was very time consuming and chokersetters were still unable to preset yarding turns because of the large bight typical of this yarding configuration.[3] Even though the capital cost of a motorized carriage is high, the resulting productivity gain might offset the additional cost over the long term.

Overall yarding productivity may also have been increased if the log loader had been used to cherry-pick wood within reach of the road prior to yarding.[4] Cherry-picking would have reduced the number of yarding hours required per treatment unit, thereby increasing overall harvesting productivity and decreasing overall cost. The hourly rate and productivity of a loader are generally higher than those of a yarder.

## Conclusions and implementation

Falling productivity averaged 222 $m^3$/6.5-h shift, and was affected by frequent and heavy snowfall accumulations. This resulted in increased walk, set-up, and snow removal times.

[2] A jump landing is a short spur, located above a main haul road, used to place the yarder on while yarding.

[3] Bight is the hazardous zone contained within lines, either slack or under tension (Tataryn 1993.)

[4] Cherry-picking refers to the use of a log loader to pick up logs from the setting within reach of the loader's boom and bring them to roadside.

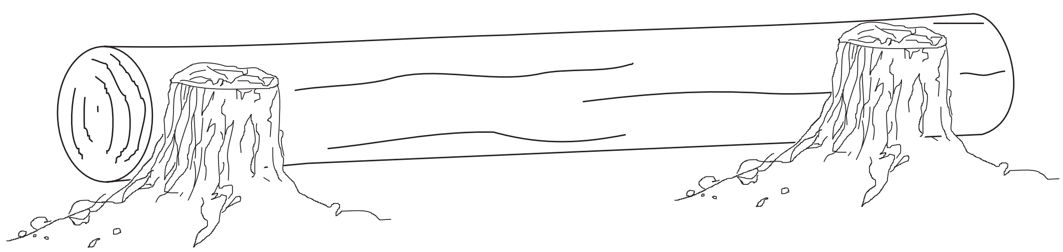

Figure 8.
Brow log.

The yarding shifts averaged 6.9 h. Overall, 80% of SMH was spent performing yarding functions with the remaining time attributed to changing yarding roads, relocating between treatment units, and servicing the yarder. The yarding crew averaged 192 $m^3$ or 69 cycles per shift at 2.8 $m^3$/cycle. Downhill yarding units rigged with a running/scab skyline system had the fastest average cycle time when standardized to 100 m slope distance at 5.76 min, followed by the uphill yarding units rigged with a shotgun system at 5.95 min, and then the uphill yarding units rigged with a northbend system at 11.35 min.

Results of a linear regression analysis indicated that slope yarding distance was not a significant factor in determining inhaul, outhaul and overall delay-free cycle time for uphill yarding. The effects of poor weather and high snowfall during uphill yarding overshadowed that of yarding distance. However, a significant relationship was found for downhill yarding.

The total stump to truck harvesting cost was estimated at \$22.25/$m^3$, comprised of \$2.40/$m^3$ for falling, \$12.11/$m^3$ for yarding, and \$7.74/$m^3$ for loading.

This study illustrated many of the challenges, such as poor stand quality, steep terrain conditions and high winter snow levels, presented by forest stands in the ICH biogeoclimatic zone. Integrating ungulate winter range requirements and timber management is important to licensees operating in many parts of the ICH zone.

Although the prescription was suitable, yarding productivity may have been improved by:

- Using a motorized slack-pulling carriage to increase lateral yarding distance and volume yarded per yarding road.
- Harvesting the cable units during the summer to eliminate snow-related delays.
- Using a brow log on small landings during uphill yarding to hold logs on the sidehill until the loader could clear them.
- Increasing the landing size, especially in two of the uphill yarding treatment units, by installing a jump landing.

## References


Boswell, B. 1999. Factors affecting productivity of skyline yarding systems: results of six case studies in northwestern British Columbia. FERIC, Vancouver, B.C. Technical Report No. TR-127. 25 pp.

Braumandl, T.F.; Curran, M.P. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. Research Branch, Ministry of Forests, Victoria, B.C. Land Management Handbook No. 20. 311 pp.

B.C. Ministry of Forests (BCMOF). 1999. Ministry of Forests Annual Report 1997/98. BCMOF, Public Affairs Branch, Victoria, B.C.

Pavel, M. 1999. Analysis of a skyline partial cutting operaion in the Interior Cedar-Hemlock biogeoclimatic zone. FERIC, Vancouver, B.C. Technical Report No. TR-125. 21 pp.

Powell, L.H. 1977. Falling decadent cedar-hemlock stands: a comparison of tree breakage and wood recovery in summer vs. winter operations. FERIC, Vancouver, B.C. Technical Report No. TR-15. 20 pp.

Tataryn, J. editor. 1993. Cable yarding systems handbook. Workers' Compensation Board of British Columbia. 175 pp.


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# Appendix I

## Equipment costs [a]

| | Madill 071 mobile tower yarder [b] (new) | Shotgun carriage (new) | John Deere 892D-LC tracked log loader (new) | Dresser TD-15C crawler tractor (used) |
|---|---|---|---|---|
| OWNERSHIP COSTS | | | | |
| Total purchase price (P) $ | 640 000 | 15 000 | 425 000 | 40 000 |
| Expected life (Y) y | 12 | 12 | 7 | 7 |
| Expected life (H) h | 17 280 | 17 280 | 14 000 | 4 900 |
| Scheduled hours per year (h)=(H/Y) h | 1 440 | 1 440 | 2 000 | 700 |
| Salvage value as % of P (s) % | 20.0 | 20.0 | 30.0 | 30.0 |
| Interest rate (Int) % | 10.0 | 10.0 | 10.0 | 10.0 |
| Insurance rate (Ins) % | 3.0 | 3.0 | 3.0 | 3.0 |
| Salvage value (S)=(s•P/100) $ | 128 000 | 3 000 | 127 500 | 12 000 |
| Average investment (AVI)=((P+s)/2) $ | 384 000 | 9 000 | 276 250 | 26 000 |
| Loss in resale value ((P-S)/H) $/h | 29.63 | 0.69 | 21.25 | 5.71 |
| Interest=((Int•AVI)/h) $/h | 26.67 | 0.63 | 13.81 | 3.71 |
| Insurance=((Ins•AVI)/h) $/h | 8.00 | 0.19 | 4.14 | 1.11 |
| Total ownership costs (OW) $/h | 64.30 | 1.51 | 39.20 | 10.53 |
| OPERATING COSTS | | | | |
| Wire rope (wc) $ | 28 500 | - | - | 2 050 |
| Wire rope life (wh) h | 1 800 | - | - | 1 800 |
| Rigging and radio (rc) | 10 500 | - | - | - |
| Rigging and radio life (rh) h | 5 700 | - | - | - |
| Fuel consumption (F) L/h | 41.0 | - | 25.0 | 10.0 |
| Fuel (fc) $/L | 0.45 | - | 0.45 | 0.45 |
| Lube and oil as % of fuel cost (t) no. | 10 | - | 10 | 10 |
| Track and undercarriage replacement (Tc) $ | 22 500 | - | 30 000 | - |
| Track and undercarriage life (Th) | 6 000 | - | 4 000 | - |
| Annual repair and maintenance (Rp) $ [c] | 42 666 | 1 000 | 48 571 | 4 571 |
| Wire rope (wc/wh) $/h | 15.83 | - | - | 1.14 |
| Rigging and radio (rc/fh) $/h | 1.84 | - | - | - |
| Fuel (F•fc) $/h | 18.45 | - | 11.25 | 4.50 |
| Lube and oil ((fp/100)•(F•fc)) $/h | 1.85 | - | 1.13 | 0.45 |
| Track and undercarriage (Tc/Th) $/h | 3.75 | - | 7.50 | - |
| Repair and maintenance (Rp/h) $/h | 29.63 | 0.69 | 24.29 | 6.53 |
| Total operating costs (OP) $/h | 71.35 | 0.69 | 44.17 | 12.62 |
| TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h | 135.65 | 2.20 | 83.37 | 23.15 |

[a] 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.

[b] The Madill 071 is no longer manufactured. Purchase price used in the cost analysis is based on the capital cost of a currently manufactured comparable machine.

[c] Annual repair and maintenance costs are calculated using 80% of the total purchase price divided by the life in years.

## Appendix II

### Labour costs

| Description | Hourly rate [a] ($/h) | Total hours (h) | Cost ($) | Cost ($/m³) |
|---|---|---|---|---|
| Falling | | | | |
| Faller [b] | 50.55 | 91.8 | 4 640 | 1.48 |
| Labourer | 28.29 | 87.7 | 2 481 | 0.79 |
| Total falling | - | - | - | 2.27 |
| Yarding | | | | |
| Yarding engineer | 29.01 | 130.5 | 3 786 | 1.21 |
| Chaser | 30.25 | 130.5 | 3 948 | 1.26 |
| Steel spar hooktender | 33.64 | 130.5 | 4 390 | 1.40 |
| Rigging slinger | 31.01 | 130.5 | 4 047 | 1.29 |
| Chokersetter | 29.01 | 130.5 | 3 786 | 1.21 |
| Total yarding | - | - | - | 6.37 |
| Loading | | | | |
| Loader operator | 32.49 | 167.8 | 5 452 | 1.74 |
| Landing bucker | 32.49 | 121.3 | 3 941 | 1.26 |
| Crawler tractor operator [c] | 31.01 | 6.5 | 202 | 0.06 |
| Total loading | - | - | - | 3.06 |
| Total labour | - | - | - | 11.70 |

[a] Hourly wage rates are based on the 1998 IWA interior wage scale.
[b] Hand faller wage rate is based on the 1998 IWA coast wage scale because no category was available for this position in the interior wage scale agreement. Falling labour costs are based on straight time with no overtime allowances.
[c] The landing bucker operated the crawler tractor when the loader operator was loading a truck.

# Appendix III

## Harvesting costs

| Description | Hourly rate ($/SMH) | Total hours (SMH) | Cost ($) | Cost ($/m$^3$) |
|---|---|---|---|---|
| Falling | | | | |
| Faller [a] | 78.84 | 91.8 | 7 064 | 2.27 |
| Saw allowance [b] | - | - | 405 | 0.13 |
| Total falling | - | - | - | 2.40 |
| Yarding | | | | |
| Labour [a] | 152.92 | 130.5 | 19 956 | 6.37 |
| Madill 071 yarder | 135.65 | 130.5 | 17 702 | 5.65 |
| Shotgun carriage | 2.20 | 130.5 | 287 | 0.09 |
| Total yarding | - | - | - | 12.11 |
| Loading | | | | |
| Labour | 95.99 | 100.0 | 9 595 | 3.06 |
| John Deere 892D-LC log loader | 83.37 | 167.8 | 13 989 | 4.47 |
| Dresser TD-15C crawler tractor | 23.15 | 6.5 | 150 | 0.05 |
| Saw allowance | - | - | 513 | 0.16 |
| Total loading | - | - | - | 7.74 |
| Total labour cost | - | - | - | 11.70 |
| Total machine cost | - | - | - | 10.55 |
| Total harvesting cost | - | - | - | 22.25 |

[a] Total hours worked by the crew is based on a crew average.
[b] Saw allowance is based on $27/shift.