SR102

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

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INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

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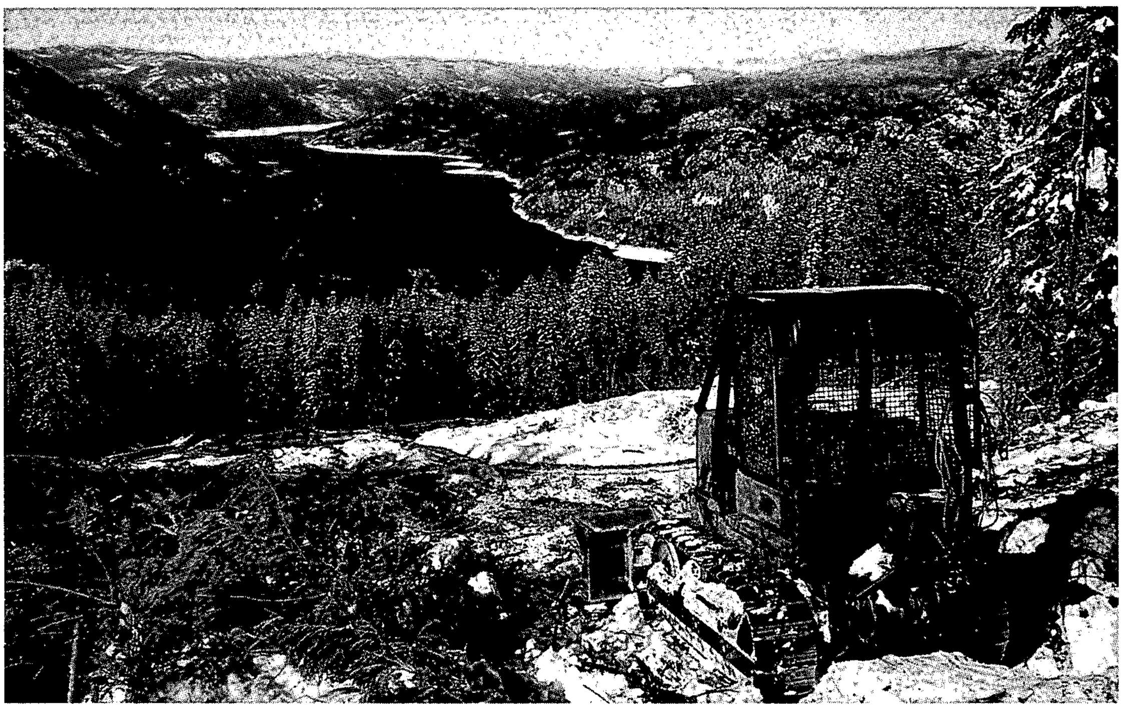

Technical Report

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Abstract

In the Kootenay Lake and Arrow Forest Districts of southeastern British Columbia, harvest planning and selection of harvesting systems must be responsive to high recreation and tourist values and the visually sensitive slopes. In 1992-93, the Forest Engineering Research Institute of Canada (FERIC) monitored harvesting on small patch clearcuts, and the British Columbia Ministry of Forests conducted site-disturbance surveys. On one study site, both ground skidding and cable yarding were used, in summer and winter seasons; at the second site, low ground pressure skidders were used and only in summer.

Acknowledgements

The cooperation of the contractors—Husbscher Logging Ltd. of Fruitvale, Wesley Construction Ltd. of Castlegar, and Sunshine Logging Ltd. of Kaslo—was vital to this study, and the authors extend their appreciation. The British Columbia Ministry of Forests—Forest Sciences Section of Nelson Forest Region, Arrow Forest District, and Kootenay Lake Forest District—initiated and then supported the project with funding through the Alternative Silvicultural Systems Research Program, and contracted the planning, harvesting, and site-disturbance surveys. The project was also supported in part by the Forestry Practices component of the Canadian Forest Service's Green Plan.

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Disclaimer

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Summary

In the Kootenay Lake and Arrow Forest Districts of southeastern British Columbia, harvest planning and selection of harvesting systems must be responsive to high recreation and tourist values, and the visually sensitive slopes. Group selection and small patch clearcuts have the greatest opportunity to meet the visual, harvesting, and biological objectives in these areas. In 1991 the Nelson Forest Region of the British Columbia Ministry of Forests (BCMOF) approached the Forest Engineering Research Institute of Canada (FERIC) to cooperate in a harvesting trial. Intermediate slopes of 30 to 50% were targeted. The harvesting trial was funded in part by the BCMOF through its Alternative Silvicultural Systems Research Program and by the Forestry Practices component of the Canadian Forest Service's Green Plan. The report format and contents are designed to meet contract obligations with these organizations.

Two study sites were chosen, one on Robson Ridge in Arrow Forest District and a second at Pilot Point in Kootenay Lake Forest District. At Robson Ridge, both ground skidding and cable yarding were used, in summer and winter seasons; at Pilot Point, low ground pressure skidders were used and only in the summer. FERIC monitored harvesting and the BCMOF conducted site-disturbance surveys.

At Robson Ridge, with the ground-skidding system in the summer, a John Deere 550 crawler-tractor produced 6.1 m^3/PMH, compared to 8.2 m^3/PMH for a Caterpillar 518 rubber-tired skidder. In the winter, productivities were 7.2 and 9.1 m^3/PMH respectively. The cable-yarding system, a Rosedale Ecologger II, produced 19.1 m^3/PMH and 17.8 m^3/PMH in the summer and winter trials respectively. At Pilot Point, a Caterpillar D4H custom skidder produced 16.5 m^3/PMH, while a KMC 2400CA produced 15.9 m^3/PMH, and an FMC 210CA 13.7 m^3/PMH.

The costs of the cable-yarding system at Robson Ridge and the low ground pressure equipment at Pilot Point were similar. At Robson Ridge the costs were \$18 and \$21/m^3 on the truck for the cable yarding in summer and winter respectively. At Pilot Point the costs, on the truck, were \$15/m^3 for the Caterpillar D4H and \$18/m^3 for both the FMC and KMC skidders. These figures are on the upper range of results for similar studies done by FERIC. The ground-skidding system at Robson Ridge was more costly, up to \$30/m^3. The patches harvested by this system had long skidding distances, and piece size was very small. Also, the contractor's machine capacity exceeded the availability of operators and volume.

The main factors affecting productivity and cost were related to planning and layout: the location of the patches with respect to the landing; length of forwarding trail; forwarding trail alignment, both along the trail and at the entrance to the block; deflection; and slope (magnitude and adverse/favourable). Equipment utilization and season of operation also had an effect, especially on cost. The investment in a good system of roads and forwarding trails is essential. The majority of difficulties during harvest within the study areas related to layout and location of patch boundaries, landings, and forwarding trails or skid roads. Many of these problems could have been avoided by making only minor changes. Better communication concerning layout, supervision, and operations would improve the success of small patch clearcut harvesting in meeting economic and environmental objectives.

In planning a small patch clearcut, it is likely that roads and trails will constitute a greater proportion of the productive land area than when developing larger cutblocks. In preparing a plan for a small patch development area, the harvesting of all patches on the forwarding trails needs to be addressed, particularly where patch size is 1 ha or less. With cable-yarding systems, if forwarding the wood with ground-based equipment is necessary, it will add substantial cost to the harvest. Average skidding or yarding distances for individual patches will be more variable than averages for conventional clearcuts (depending on the proximity of the landing). This may impact on the productivity and cost for specific entries.

The site-disturbance surveys identified high road and landing disturbance at Robson Ridge, but this was due in part to the method of calculating the disturbance. Allocating the disturbance due to access and service structures (haul roads, landings, and forwarding trails) over the total harvestable area is a more realistic approach than on a patch-by-patch basis. The within-patch skidding disturbance on the patches harvested by the small crawler-tractor, high-track, and flexible-track skidders showed high variation within each skidder type. The lower levels of disturbance were at Pilot Point, with the lowest for the KMC skidder. This lower level of disturbance must be viewed as a sample only, and the additional cost of harvesting with this equipment must also be considered.

INTRODUCTION

Public perception of forest harvesting has necessitated changes to harvesting patterns to meet visual objectives. In the Kootenay Lake and Arrow Forest Districts in southeastern British Columbia, harvest planning and selection of harvesting systems must be responsive to high recreation and tourist values, and to the visually sensitive slopes prevalent throughout the region. The visual quality objective applied to these areas is "Partial Retention", and the use of single tree selection, group selection, or small patch clearcuts is recommended to reduce visual impact of harvesting (BCMOF 1981). The incidence of disease within these stands, *Armillaria oystoyae*, and their susceptibility to blowdown make partial cutting alternatives inappropriate. Therefore, group selection and small patch clearcuts have the greatest opportunity to meet visual, harvesting, and biological objectives.

In 1991 the Nelson Forest Region of the British Columbia Ministry of Forests (BCMOF) approached the Forest Engineering Research Institute of Canada (FERIC) to cooperate in a harvesting trial involving small patch clearcuts. The BCMOF defined slopes of 30 to 50% as most problematic when selecting appropriate harvesting systems. These slopes are potentially suited to either ground-based or cable systems, and the BCMOF wanted information on the effectiveness of equipment alternatives in harvesting small patches. This study was funded in part by the BCMOF through its Alternative Silvicultural Systems Research Program and by the Forestry Practices component of the Canadian Forest Service's Green Plan.

In 1991-92, the project objectives were developed by FERIC and the BCMOF; and site selection, layout, and harvesting proceeded, with field work completed in late 1993. This report presents the study results, in a format and content to meet contract obligations of the funding organizations.

STUDY OBJECTIVES

The study objectives were to:

1. Evaluate and compare productivities, costs, and site-disturbance levels for harvesting systems of interest to the Forest Districts concerned, working in small patch clearcuts.
2. Identify operational factors affecting or limiting the use of the systems in small patch clearcut operations.
3. Identify planning and development requirements for each harvesting system when applied to small patch clearcut operations.

PROJECT PLANNING AND ORGANIZATION

Representatives from the BCMOF's Nelson Forest Region, Kootenay Lake Forest District, Arrow Forest District, and from FERIC visited potential sites within the two Districts and identified one area in each District that met the slope criteria; both were part of the Small Business Forest Enterprise Program. The two areas, Robson Ridge near Castlegar in the Arrow Forest District, and Pilot Point near Crawford Bay in the Kootenay Lake District, were visible primarily to boaters (Figure 1). The Pilot Point site is also within the view of Kootenay Lake ferry passengers, and it is used by hikers and hunters.

The BCMOF hired a local consultant to prepare a total-chance plan for each area, and to define the road system

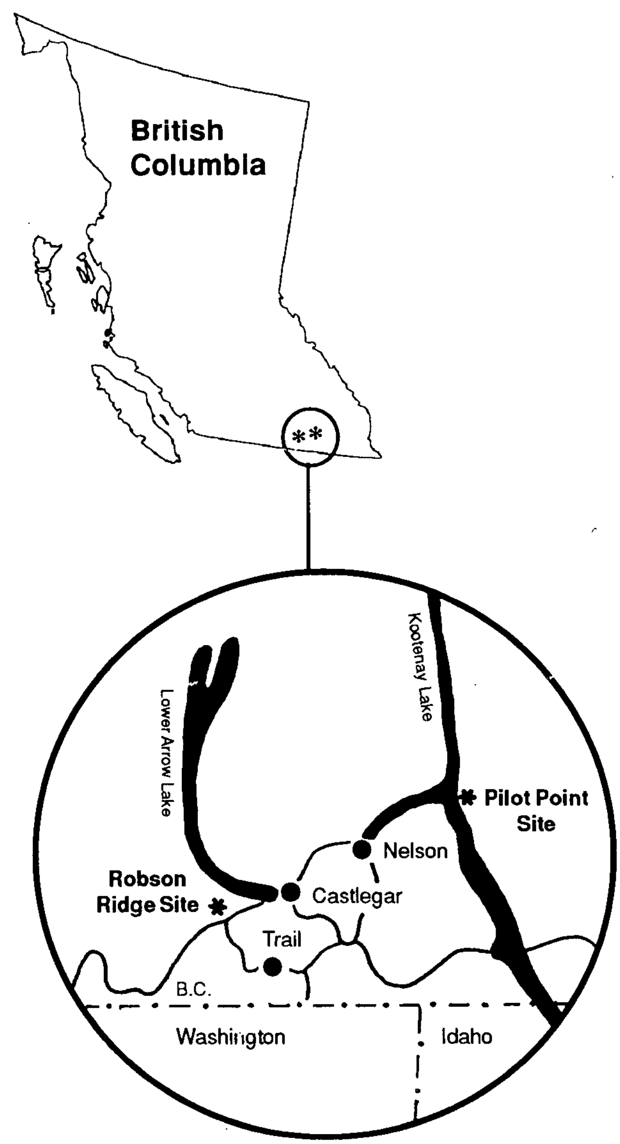


Figure 1. Location of study sites.

and patches for the planned harvest.[1] The two areas had different criteria and each plan was developed according to specific requirements and constraints. The interval between entries depended on the degree of "green-up" desired, the level of harvest per entry, and the rotation period. At Robson Ridge, the road system was designed and constructed for conventional clearcutting. The patch size here was specified as approximately 3 ha, with 12 patches to be harvested in the first entry. The timber management objective is to remove one-third of the volume in each entry, with entries occurring every 25 to 30 years. At Pilot Point, the road had been developed with patch cutting as the probable pattern of harvest; road location was, however, influenced strongly by the presence of a lakeshore park. The objective is to remove one quarter of the volume at twenty-year intervals; patch size averaged 1.1 ha, with 17 patches scheduled for the initial entry. Maps of each development area showing road, landing, and patch location are in Appendix I.

Following planning and layout, the wood volumes in the patch cuts were advertised for sale. The patches in each area were separated into four groups to allow comparison of two harvesting systems in both summer and winter seasons. Cable yarding and ground skidding with a small crawler-tractor were the two harvesting systems selected for Robson Ridge; two low ground pressure systems—a flexible-track skidder and a small high-drive crawler-tractor—were selected for Pilot Point.

STUDY METHODS

To determine productivity and cost of the harvesting operations, FERIC collected both shift-level and detailed-timing information on the harvesting phases. Servis recorders were mounted on the mobile equipment to document productive time and the crews' hours. A FERIC researcher was on site most operating days for the duration of the study and used a stopwatch to sample the skidding/yarding cycle times. At Pilot Point, logs were scaled at the landing to determine average piece size. Overall harvest volume was obtained from the BCMOF records and billings for the sales. Scale volumes were available only for the total license, not individual patches. Therefore, where FERIC used patch volumes, these were prorated using inventory information. FERIC's projected harvesting costs include the costs of machine ownership and operation, and labour, and exclude the costs of supervision, overhead, development, and crew transportation. Costs by phase were calculated using IWA labour rates and FERIC-calculated machine costs (Appendices II, III, and IV).

Production and timing data were collected and compiled by individual patches and summarized by harvesting system and season of harvest. Because the patches were so small, combining the data for harvesting systems provides the most representative information. Patches were considered individually to identify factors influencing production rates.

The consultant hired by the BCMOF to conduct the site disturbance surveys used the BCMOF's most recent sampling procedure.[2] A summary of the results of these surveys is included in this report.

SITE DESCRIPTIONS

The site descriptions were obtained primarily from the Pre-Harvest Silviculture Prescriptions developed by the BCMOF for each area and from the total-chance plans mentioned earlier.

Robson Ridge

The Robson Ridge site was located on the Gem Hill Forest Service Road, 43 km southwest of Castlegar (Figure 1). The forest within the 610-ha project area is primarily fire origin, and is 80 to 100 years of age. Fifty-three per cent of this area is currently operable. The patches were all within the Columbia-Shuswap Moist Warm Interior Cedar-Hemlock ecosystems (ICHmw2 (01) and (03)) (Braumandl and Curran 1992). Species composition was primarily Douglas-fir (37% of estimated volume within the study patches), lodgepole pine and western red cedar (18% each), western larch (10%), western hemlock (9%), and Engelmann spruce (8%).

Elevations of the study patches ranged from 1200 to 1500 m. The terrain was highly variable, with frequent slope breaks and exposed rock. Slopes ranged between 30 and 50%. Soil texture included silty loams, loams, and sandy loams, with 30-60% coarse fragments. Sensitivity to disturbance hazard rating was Moderate for all but two of the patches; one was Moderate/High and the other was High/Very High. Five of the twelve patches were classified with visual quality objectives of Partial Retention while the others were Modification (BCMOF 1981).

[1] Timberland Consultants Ltd., "Total Chance Development of the Upper and Lower Gem Hill Road System," report prepared for BCMOF's Arrow Forest District; October 1991; unpublished.

Timberland Consultants Ltd., "Pilot Point FERIC Project," report prepared for BCMOF's Kootenay Lake Forest District; December 1991; unpublished.

[2] Mike Curran, Nelson Forest Region, BCMOF; personal communication, February 1994.

Pilot Point

The Pilot Point study area was located on the east side of Kootenay Lake, 10 km from the ferry terminal at Kootenay Bay (Figure 1). The 17 study patches were within an 82-ha planning unit. Tree age ranged from 80 to 120 years, with occasional veterans older than 250 years. Sixty-eight per cent of the area is currently operable. The study patches were all within the Dry Warm Interior Cedar-Hemlock ecosystems (ICHdw (01a) and (01b)) (Braumandl and Curran 1992). Species composition was primarily Douglas-fir (56%) and western red cedar (21%), with grand fir and western hemlock at 9 and 8% respectively. Engelmann spruce, western white pine, lodgepole pine, ponderosa pine, western larch, and birch were also present on the site. In this study area, the Pre-Harvest Silviculture Prescription called for 10-15 leave trees per hectare to meet biodiversity, visual, and wildlife objectives.

Elevations of the study patches ranged from 755 to 825 m. Slopes ranged from 15 to 50%, but most were within the 30 to 50% range. Many of the slopes were short, and frequently changed aspect. Soil texture was silty loam, with 35-40% coarse fragments. Sensitivity to disturbance hazard rating was Moderate/High. The area was classified with the visual quality objective of Partial Retention.

HARVESTING SYSTEMS AND OPERATING PROCEDURES

Ground-Skidding System at Robson Ridge

In the patches harvested by the small crawler-tractor/rubber-tired skidder system, trees were hand felled and skidded full tree to the landing. The stems were delimbed and bucked to length manually at the landing, and the logs were then sorted, decked, and loaded onto trucks with a Caterpillar 966 front-end log loader. Both a John Deere 550 small crawler-tractor and a Caterpillar 518 rubber-tired skidder skidded stems to the landing (Figures 2 and 3). The John Deere 550 also constructed skid roads, concurrently with skidding. The number of crew members varied during the study period. Each crew member was responsible for one primary task, but his activities were not limited to that task. Because only one full-time skidder operator was available for the study, the faller, loader operator, and bucker occasionally operated the second skidder. The truck driver occasionally bucked logs while his truck was being loaded, loaded the truck himself, or remained on site to sort and deck logs. This flexibility in task responsibility is common in many contractor operations. Machine operators had varying levels of skill, from novice through to very experienced.

During the winter the faller, sometimes with assistance from other workers, dug snow from the base of trees to achieve low stumps. A faller was added part time in winter to compensate for the lower felling productivity.

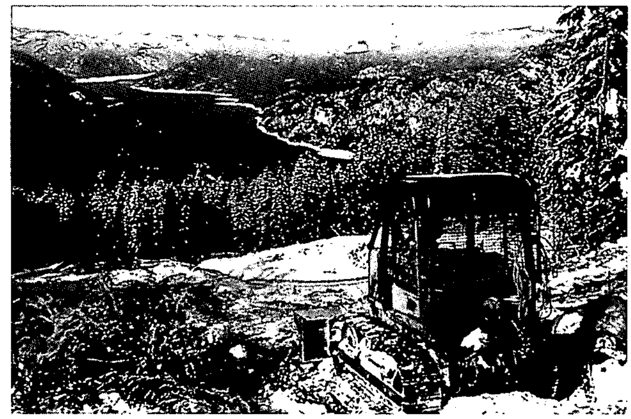


Figure 2. John Deere 550 crawler-tractor at Robson Ridge.

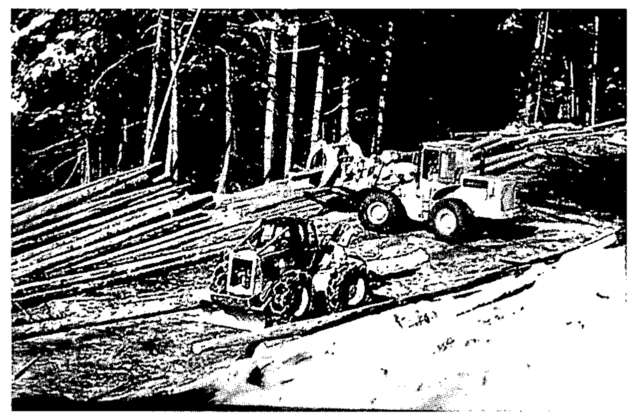


Figure 3. Caterpillar 518 rubber-tired skidder at Robson Ridge.

The contract specified use of the small crawler-tractor because of the low maximum allowable site-disturbance levels. Machine restrictions defined by the BCMOF limited the use of the rubber-tired skidder to skidding along haul roads, on some bench areas, and on some main skid roads.

Cable-Yarding System at Robson Ridge

The contractor used a skidder-mounted two-drum Rosedale Ecologger II for the cable-yarding portion of the study (Figure 4). The yarder was equipped with a 13.5-m tower and was rigged with a standing skyline and a gravity carriage return for uphill yarding. During the summer study a Maki Mini-Mak I carriage was used. This was replaced by a newer model Maki II carriage for the winter study. Both are radio-controlled clamping carriages; the Maki I had a manual slack-pulling system, and the Maki II was equipped with a powered slack-pulling system. Four chokers were used in both cases.

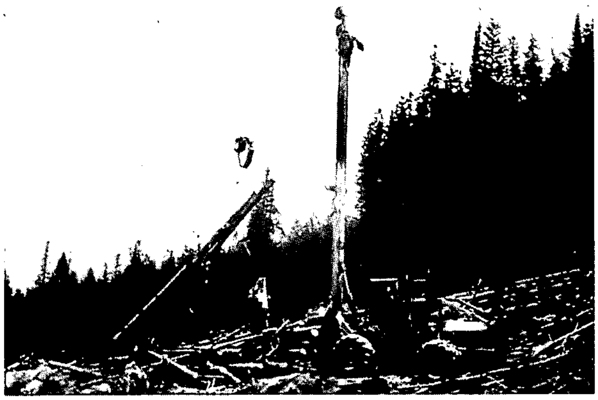


Figure 4. Rosedale Ecologger II at Robson Ridge.

Maximum yarding distance for the patches was about 230 m. Yarding roads were located at 25- to 40-m spacings measured at the tailhold end of the yarding road. The slack-pulling capability of the carriages permitted lateral pulling of the mainline and chokers. The mainline was pulled diagonally away and downslope from the carriage.

In most cases, skyline tailholds were rigged at stump height; and, occasionally, when additional lift was needed, backspar trees were rigged at 7- to 10-m heights. On some sites the locations of yarding roads were determined by the availability of suitable backspar trees. Occasionally the skidder or crawler-tractor served as a guyline anchor for the yarder where suitable stumps were unavailable.

Trees were hand-felled downslope, in a slight herringbone pattern. As with the ground-skidding system, falling productivity was low in the winter and an additional full-time member was added to the crew to shovel snow from the bases of the trees prior to falling. One choker setter worked along the yarding corridor. Stems were yarded full tree to the landing, but the occasional large tree had to be bucked within the patch. The yarder operator generally unhooked the chokers, assisted occasionally by the bucker. Trees were manually bucked to length and delimbed at the landing by the bucker or the loader operator. A Caterpillar 215 BSA hydraulic log loader was well suited to sorting, decking, and loading stems on many of the small landings on the study site.

Most of the crew assisted in setting up, changing, and rigging yarding roads. The skyline was usually rigged at or beyond the boundary. However, on occasions when the faller had not completed falling on a yarding road, a backspar partway into the patch was rigged temporarily to avoid downtime of the yarder. When falling was completed in the remaining area, the skyline was extended to a backspar at the patch boundary.

The Caterpillar 518 rubber-tired skidder was used to skid logs close to the landing and along the road, and, in some cases, in areas with poor deflection, adjacent to the road. The International Dresser TD15E prepared and cleared the landing and acted as a guyline anchor for the yarder. Both machines worked only part-time.

The crew members were well experienced and had worked together for several years.

Ground-Skidding System at Pilot Point

Although a frozen-ground trial was planned, a variety of scheduling and logistical circumstances caused the Pilot Point site to be harvested in two fall seasons in 1992 and 1993. Some snow fell at the end of the 1992 period, but temperatures were not low enough to freeze the soil. The 1992 and 1993 results for this area are combined.

All of the study patches at Pilot Point were harvested by one contractor, but some of the crew members changed from one year to the next. In 1992, the crew consisted of two skidder operators, two fallers, one bucker, one loader operator, and one foreman (owner). There was some flexibility in tasks among the crew. The fallers occasionally acted as buckers or choker setters; the bucker set chokers; and the foreman felled, bucked, set chokers, cleared snow, and performed other jobs as was necessary.

In 1993, the crew again consisted of two skidder operators (one of whom was the foreman), two fallers, two buckers, and one loader operator. Jobs were not shared to the same extent as in the 1992 trial period. When one of the skidders was down for repair, its operator, and the bucker associated with it, would perform other tasks, but this occurred infrequently.

FERIC did not differentiate time on specific patches, or groups of patches, for falling, decking by the loader, or loading. The productivity and cost of these activities are expressed for the whole of the volume.

The equipment used in 1992 consisted of an FMC 210CA flexible-track skidder and a Caterpillar D4H custom line skidder (Figures 5 and 6). Each machine was assigned half of the patches within the study area. In 1993, the FMC was replaced by a new KMC 2400CA flexible-track skidder (Figure 7). In both trial periods, when the landing for one of the skidders was filled, one machine would work in the other machine's patch rather than stay idle.

An older-model Caterpillar 966 front-end loader was

Figure 5. FMC 210CA flexible-track skidder at Pilot Point (1992). Note the adverse skid.

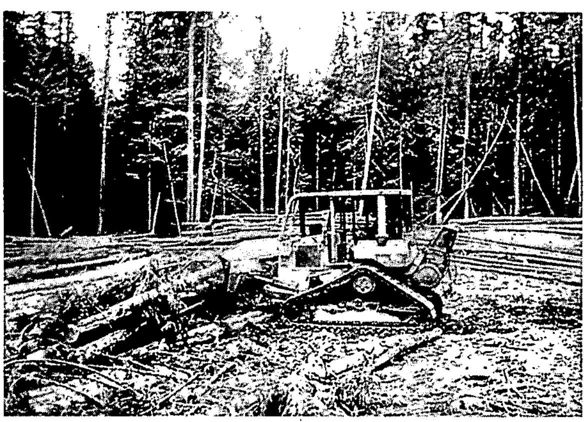


Figure 6. Caterpillar D4H custom line skidder at Pilot Point (1992 and 1993).

Figure 7. KMC 2400CA flexible-track skidder at Pilot Point (1993).

used in both years to deck on the landing and to load logging trucks. In the 1993 portion of the study, a loader operator was unavailable for several days. This disrupted the skidding and may have had an indirect impact on the productivity of the skidders during that time period. Because of restricted space the loader could not be used on four of the patches in 1993; therefore, self-loading logging trucks were used.

All of the forwarding trails were felled and skidded in 1992. The Caterpillar D4H did any work necessary in trail construction, but these trails had minimal excavation. Slash or windthrow were pushed aside, but cuts and fills were generally not required.

Trees were hand felled and skidded full tree to the landing. The skidders spread and aligned the stems for the buckers. The skidders also did some decking, but most sorting and decking were done by the loader. The crew members were generally well experienced in their tasks.

RESULTS

Harvesting Productivity, Ground-Skidding System at Robson Ridge

Shift-Level Productivity. Table 1 summarizes shift-level time distributions by season of harvest and skidder type. The John Deere 550 crawler-tractor had more scheduled machine shifts than the Caterpillar 518 rubber-tired skidder for both the summer and winter harvested patches because of the restrictions imposed on the use of the rubber-tired skidder.

Both the small crawler-tractor and the rubber-tired skidder had high rates of machine availability (>96%); however, the utilization percentages were considerably lower due to the significant amounts of "idle" time. This resulted because crew were not available to operate both skidders full time and because of duty sharing amongst the crew. Idle time for the rubber-tired skidder when it was parked on site because of BCMOF restrictions is excluded from the data analysis. The restrictions meant that, even with a full-time operator, utilization of the machine would have been low.

Machine utilization levels were indirectly influenced by harvest season because the steeper and rockier sites were reserved for winter harvest. Both terrain conditions favoured the small crawler-tractor over the rubber-tired skidder. Utilization levels varied widely between patches due to a combination of site factors (including terrain, slope and snow condition) and operator preference.

Table 1. Machine Productivity, Robson Ridge: Shift-Level Timing Summary

	Summer		Winter	
	John Deere 550	Caterpillar 518	John Deere 550	Caterpillar 518
Productive machine hours (PMH)				
Skidding (h)	236.1	138.2	208.6	176.6
Trail building (h)	7.1	0.0	11.4	0
Landing construction (h)	3.5	0.0	0.0	0.0
Delays				
Non-mechanical (h)	68.4	102.3	11.4	16.2
Mechanical (h)	11.5	6.5	6.1	2.3
Idle (h)	0.0	0.0	121.2	80.1
Scheduled machine hours (SMH)	326.6	247.0	358.7	275.2
Shifts (no.)	43	31	45	33
Availability (%)	96	97	98	99
Utilization (%)	75	56	61	64
Total volume (m^3)	1439	1139	1499	1609
Productivity (m^3/PMH)[a]	6.1	8.2	7.2	9.1
Productivity (m^3/SMH)	4.4	4.6	4.2	5.8
Average tree size (m^3)[b]	0.41		0.63	

[a] Excluding time spent building trails and landings. [b] From cruise.

The crawler-tractor was responsible for skid-road construction and clearing trails. Skid roads were built concurrently with skidding, and construction activity accounted for 3% of the crawler-tractor's productive machine hours (PMH). Clearing snow from skid roads and trails was important in winter to maintain skidding productivity.

Mechanical delay times for both machines was 4% or less of scheduled machine hours (SMH) and included in-shift repairs and minor servicing. Some repairs and major servicing occurred out-of-shift, usually on weekends.

Season of harvest did not appear to influence the delay percentages for the rubber-tired skidder and the crawler-tractor. Delays included maintaining or ploughing haul roads or landings, assisting other equipment, coffee breaks, discussions with BCMOF personnel, putting in waterbars, and moving to new work areas. Only the latter delay can be attributed to the patch size and layout. It was a minor delay because the distances between patch cuts were generally short and equipment could easily be walked between operating areas.

Table 1 also summarizes production for each skidding machine by season of harvest. The crawler-tractor produced 6.1 m^3/PMH in the summer, compared to 8.2 m^3/PMH for the rubber-tired skidder. Both machines were more productive in the winter, 7.2 and 9.1 m^3/PMH respectively, because cycles were shorter then (as indicated later in the detailed timing section) and piece size was larger. The crawler-tractor had lower productivity than the rubber-tired skidder in both seasons, with the skidder producing 34% and 26% more in summer and winter respectively.

Detailed Timing. Detailed-timing summaries are shown in Table 2 for the crawler-tractor and the rubber-tired skidder, by season of harvest.

Average total cycle time of the crawler-tractor was more than ten minutes higher, or almost 90%, in the summer patches than in the winter patches. For the rubber-tired skidder, average total cycle time was 25% higher in the

Table 2. Average Skidding Cycle Results, Robson Ridge: Detailed-Timing Evaluation

	Summer		Winter	
	John Deere 550	Caterpillar 518	John Deere 550	Caterpillar 518
Cycles timed (no.)	114	65	195	95
Skidding cycle elements				
Travel empty (min)	4.79	2.33	1.70	1.72
Position (min)	1.23	1.00	0.88	0.83
Hook (min)	5.70	6.05	3.88	5.47
Winch (min)	1.23	1.24	0.48	0.64
Travel loaded (min)	4.30	2.05	1.47	1.38
Landing (min)	3.91	2.96	2.41	2.59
Minor delay[a] (min)	1.64	0.96	1.30	0.65
Total cycle time (min)	22.80	16.59	12.12	13.28
Skidding conditions				
Skidding distances				
Travel empty (m)	245	261	103	146
Travel loaded (m)	211	223	91	118
Logs/cycle (no.)	5.4	5.9	3.8	4.4

[a] Delays of less than 10 min duration.

summer patches. The longer travel times, both empty and loaded, were expected as the average skidding distances were considerably longer for the summer patches.

When individual elements of the cycle are examined for the crawler-tractor, the results indicate that position, hook, winch, and landing times were all significantly higher for the summer patches than for the winter patches. These increases are attributed at least in part to the greater number of pieces per cycle in the summer season. For the rubber-tired skidder, winch time and logs/cycle were significantly higher for the summer-harvested patches.

For summer and winter respectively, minor delays accounted for 7% and 11% of the crawler-tractor's skidding cycle time, and 6% and 5% of the rubber-tired skidder's cycle time. The majority of minor delay time for the crawler-tractor was due to building and clearing skid roads and skid trails during the skidding cycle—especially in winter. While this activity is productive, within a skidding cycle it acts as a delay. Minor repairs; waiting for the other skidder and loader to move; and talking to other crew members, BCMOF personnel, and others also affected both machines. Except for additional time spent making skid roads and trails on snow packs, which was minor in extent, none of the delays was seasonally related.

For both machines, the differences in cycle times were not reflected proportionally in the productivity summaries (Table 2). The distribution of detailed-timing samples among the patches differed from the actual distribution of shifts worked in each patch. This may have produced unbalanced sampling of some machine operators, site conditions, and stand conditions (including tree size).

Harvesting Productivity, Cable-Yarding System at Robson Ridge

Shift-Level Productivity. Shift-level time distributions for the Ecologger cable yarder are summarized in Table 3 by season of operation. The yarder worked for 33 shifts during the summer study and 37 shifts during the winter study. Machine utilization was 78%.

Productive machine time included yarding activities as well as time spent rigging and moving skyline roads and tower anchors. This latter activity accounted for about 7% of SMH for both summer and winter. Distribution of productive time and delay times did not appear to be seasonally influenced.

The majority of the non-mechanical delay was idle time, i.e. when the yarder was not required to work. The yarder was idle during set-up on a patch, while a skidder skidded logs accessible from the haul road, or when a landing was cleared and organized. The yarder was also idle near the end of operations when the last of the decked logs were loaded and the landing was cleaned. Other delays included moving to a new patch, coffee breaks, and other minor operational delays. Mechanical delays were 1% to 4% of SMH, and included minor repairs.

The yarder produced 19.1 m^3/PMH during summer and 17.8 m^3/PMH during winter (Table 3). The number of cycles per PMH was almost the same for both seasons (Table 3). Volume production is, however, slightly higher in summer than in winter, probably due to the larger piece size and greater volume per cycle in summer. The carriage was equipped with four chokers at all times, although the number of pieces in each cycle varied depending on log size and availability of pieces at the hooking site.

Detailed Timing. The total cycle time (excluding rigging time) averaged 5.01 min for the summer patches and 5.45 min for the winter patches (Table 4). The greater average yarding distance on the winter patches accounted for some of the extra cycle time during outhaul and inhaul. Lateral yarding times were significantly different between seasons, but lateral yarding accounted for only a small portion of total cycle time for both seasons. Lateral yarding time was greater in winter, probably because logs were difficult to pull free from the snowpack. The number of logs/cycle was also significantly higher in summer than in winter, again because of the snowpack problems.

Minor delays accounted for about 7% of total cycle time for summer and about 5% for winter (Table 4). For both seasons the most significant delays were waiting for the loader to clear the decking area, and hangups during inhaul, either on the yarding road or at the landing edge. No significant delays were attributed to seasonal effects.

Harvesting Productivity, Ground-Skidding System at Pilot Point

Shift-Level Productivity. Table 5 describes the time distribution for the three machines used on the Pilot Point study patches. The Caterpillar D4H worked a larger proportion of total time than either the FMC 210CA or KMC 2400CA, although a portion (11%) of this consisted of skidding trees from the right-of-way of forwarding trails. All three machines performed their primary function of skidding for similar portions of their shifts (66-69%). Both the Caterpillar D4H and the FMC had major breakdowns during the study, resulting in mechanical delays of greater than 10% of scheduled time. The KMC was a new machine and did not experience significant mechanical problems. Non-mechanical delays, however, accounted for 26% of the KMC's time. Seven per cent was due to truck activity on the road or landing which blocked the skidder's access to the landing. Also, the operator of the KMC was the owner of the opera-

Table 3. Cable-Yarder Productivity, Robson Ridge: Shift-Level Timing Summary

	Summer	Winter
Productive machine hours (PMH)		
Yarding (h)	187.2	214.8
Rigging (h)	19.1	19.3
Delays		
Non-mechanical (h)	55.3	53.9
Mechanical (h)	2.8	11.4
Scheduled machine hours (SMH)	264.4	299.4
Shifts (no.)	33	37
Availability (%)	99	96
Utilization (%)	78	78
Cycles (no.)	2117	2375
Cycles/PMH (no.)	10.3	10.1
Total volume[a] (m^3)	3933	4170
Productivity (m^3/PMH)	19.1	17.8
Productivity (m^3/SMH)	14.9	13.9
Average stem volume (m^3)	0.80	0.61

[a] Excluding volume that was ground skidded.

Table 4. Average Yarding Cycle Results, Robson Ridge: Detailed-Timing Summary

	Summer	Winter
Cycles timed (no.)	1076	500
Yarding cycle elements		
Outhaul (min)	0.31	0.40
Hook (min)	2.10	2.16
Lateral yard (min)	0.35	0.48
Inhaul (min)	0.75	0.95
Deck (min)	0.20	0.23
Unhook (min)	0.97	0.95
Minor delay[a] (min)	0.33	0.28
Total cycle time (min)	5.01	5.45
Yarding distance (m)	108	137
Logs/cycle (no.)	4.1	3.6

[a] Delays of less than 10 min duration.

Table 5. Machine Productivity, Pilot Point: Shift-Level Timing Summary

	Caterpillar D4H	FMC 210CA	KMC 2400CA
Productive machine hours (PMH)			
Skidding (h)	247.5	146.9	146.4
Building and skidding logs from forwarding trails (h)	38.2	10.8	n.a
Skidding other machines' patches (h)	4.5[a]	n.a.	9.7[b]
Delays			
Non-mechanical (h)	28.4	30.7	58.6
Mechanical (h)	39.9	27.0	8.3
Scheduled machine hours (SMH) (h)	358.5	215.4	223.0
Shifts (no.)	42	25	26
Availability (%)	89	87	96
Utilization (%)	81	73	70
Total volume (m^3)[c]	4312	1963	2401
Productivity (m^3/PMH)[d]	16.8	13.4	15.9
Productivity (m^3/SMH)	12.0	9.1	10.8
Average stem volume (m^3)[e]		Overall 0.83	
Average piece size (m^3)[f]	1.07	1.00	0.83

[a] On KMC patches. [b] On D4H patches. [c] Patch volume only. Total volume prorated by cruise for each patch.
[d] PMH includes time spent by other skidders and excludes time spent on forwarding trails. [e] From cruise.
[f] From FERIC scale sample.

tion, and some delay time was attributed to crew supervision. For 7% of the KMC's time there was no operator for the loader and the landings were filled. On some occasions the KMC worked on the D4H's patches rather than be idled by landings that were filled with logs (4%).

Volumes were allocated to each skidder by distributing the total scale volume among the patches based on the cruise volume for each patch. Average tree size (net volume) from the cruise was 0.83 m^3 (Table 5). FERIC also scaled samples of skidded logs for each skidder, and determined that average piece size ranged from 0.83 m^3 for the KMC, to 1.00 m^3 for the FMC, to 1.07 m^3 for the Caterpillar D4H. Volume productivity is calculated using only the skidding time for the patches (excluding skidding of forwarding trail right-of-way logs) (Table 5). On this basis, the Caterpillar D4H produced 16.8 m^3/PMH, while the KMC produced 15.9 m^3/PMH, and the FMC produced 13.4 m^3/PMH. Assuming the sample scale is representative, this suggests that with equal piece sizes the KMC would skid as much or more than the Caterpillar D4H. However, only one of the four patches skidded by the KMC was accessed by a forwarding trail (Patch R, 160-m long, Appendix I), whereas seven of the nine patches skidded by the Caterpillar D4H were accessed on forwarding trails of 50 to 173 m in length. These longer skidding distances influenced its productivity. The FMC worked on four patches, three of which had no, or very short, forwarding trails, and the remaining one had the longest forwarding trail on the study block (217 m). However, the FMC's adverse skidding (Figure 5) explains its lower productivity, compared to the two other machines.

Detailed Timing. Detailed-timing results for the Pilot Point patches are shown in Table 6. Although these results are not representative of all patches, they show some differences in cycle elements that are due to the characteristics of the patches or operators. For example, the KMC and the FMC had different operators, and the skid-

Table 6. Average Skidding Cycle Results, Pilot Point: Detailed-Timing Summary

	Caterpillar D4H	FMC 210CA	KMC 2400CA
Cycles timed (no.)	140	61	162
Skidding cycle elements			
Travel empty (min)	2.41	2.66	1.43
Position (min)	1.26	1.71	0.81
Hook (min)	6.00	6.11	5.40
Winch (min)	0.93	2.16	0.59
Travel loaded (min)	2.82	3.31	1.91
Landing (min)	3.57	3.45	2.82
Delay[a] (min)	0.80	1.39	0.86
Total cycle time (min)	17.79	20.79	13.82
Skidding conditions			
Skidding distances			
Travel empty (m)	141	188	108
Travel loaded (m)	134	167	100
Logs/cycle (no.)	7.4	6.9	6.7

[a] Delays of less than 10 min duration.

ding methods employed by the two operators were different with respect to patch characteristics. The FMC had the highest average time in winch; this was due to combinations of terrain and leave trees within the patches necessitating manoeuvring. Every element, except landing, was greatest for the FMC. The sample for this machine described a longer skidding distance than the other two machines, as reflected in the larger travel empty and travel loaded elements. Number of logs per cycle was greatest for the Caterpillar D4H (7.4) with 10% fewer for the KMC and FMC.

Harvesting Costs

Tables 7, 8, and 9 present the projected costs, on the truck, by phase for the study areas. The details of the costing for each operation are given in Appendices II, III, and IV. The cost of harvesting is highest, for all phases, for the ground-skidding operation at Robson Ridge, at \$30.21 and \$28.94/m^3 for summer and winter respectively (Table 7). Low machine productivity resulted from long skidding distances, small piece size, and under-utilization of equipment. The loading and bucking costs are high compared to the other two systems, reflecting the low volume of wood passing through the landing. Because this operation had a large component of idle time, the costs were re-calculated assuming 80% utilization. Although this reduced the skidding cost by \$2/m^3 for both seasons, the impact was not great.

In the cable-yarding system, cost by season was similar for all phases except falling (Table 8). To keep stump heights low, the contractor added a person to assist the faller by digging snow from around the trees. Falling cost in the winter was twice that experienced in the summer. Yarding/skidding cost includes the crawler and rubber-tired skidder on site. These machines were used intermittently and were costed as used equipment.

Table 9 outlines the costs for the Pilot Point operation. Both the falling and loading/bucking costs are similar to those calculated for the cable-yarding system at Robson Ridge. The cost of skidding is \$3/m^3 less, or 33 to 35% less for the D4H than either the FMC or KMC equipment. Productivity of the D4H was greater than that of the FMC. As well, the calculated hourly cost of the KMC, in particular, was greater than that of the D4H. Track and undercarriage cost for the FMC/KMC equipment is a large component of the hourly cost.

Site Disturbance

In the fall of 1993, the BCMOF contracted site-disturbance surveys on all the ground-skidded patches to determine the disturbance due to haul roads and landings and ground-skidding activities (BCMOF 1993; Curran and Thompson 1991). Although the PHSPs were done in 1991, 1993 criteria were used in the surveys. Site disturbance within each patch was attributed to that patch.

However, haul roads, landings, and forwarding trails were assigned differently for Robson Ridge than for Pilot Point, as described below.

At Robson Ridge, the road system was developed prior to the decision to harvest with small patch clearcuts. As well, each patch had a separate PHSP. When the site-disturbance surveys were conducted, roads and landings contiguous to a patch were assigned to that patch (Table 10). The PHSP specified disturbance levels due to landings only and did not include the haul roads. At Pilot Point, the road system was developed with the objective of small patch harvest, and accessed all of the 82 ha of harvestable timber. One PHSP was developed for all of the patches within the 1992-93 harvest. Therefore the decision was made to attribute the road, landing, and forwarding trail disturbance to the whole 82 ha rather than the harvested patches (Table 11). During the re-entries some additional forwarding trails would be necessary, but these were believed to be few.

Table 7. Costs, Ground-Skidding System, Robson Ridge: Summary

	Summer	Winter
Total volume scaled (m^3)	2578	3108
Falling ($/m^3$)	5.18	6.79
Skidding ($/m^3$)	13.20	11.95
Loading/bucking ($/m^3$)	11.83	10.20
Total cost on the truck ($/m^3$)	30.21	28.94

Table 8. Costs, Cable-Yarding System, Robson Ridge: Summary

	Summer	Winter
Total volume scaled[a] (m^3)	4107	4314
Falling ($/m^3$)	2.13	4.29
Yarding/skidding ($/m^3$)	8.98	9.81
Loading/bucking ($/m^3$)	6.92	6.86
Total cost on the truck ($/m^3$)	18.03	20.96

[a] Including volume that was ground skidded.

At Robson Ridge, the disturbance due to roads and landings was very high for some patches (Patches 31, 68, 24, and 100, Table 10). Patch 31, with 42.7% disturbance, was a wedge-shaped patch bounded by two roads. Patch 24 included a large landing which serviced Patches 19 and 31 as well. Landing disturbance for both the ground-skidded and cable-yarded patches was less than the levels specified in the PHSPs, except in the case of Patch 24.

Within the ground-skidded patches, site disturbance related to skidding ranged from 6.8 to 15.8%. Patch 31 had the lowest disturbance, in part because the haul road was used as the skid road. In comparison, Patch 68, on steep terrain, showed the highest disturbance of the Robson Ridge patches. For all patches, the skidding disturbance was greater than the levels estimated in the PHSPs.

The BCMOF estimated the disturbance due to haul roads, as 8% allocated over the total development area at Robson Ridge. This figure includes roads only, and is a more realistic number to attribute to road disturbance for harvesting of small patch clearcuts. If forwarding trials had been included, which were developed for future harvests as well as the current harvest, then road disturbance would have been overstated.

At Pilot Point, the combined road, forwarding trail, and landing disturbance over the whole area was 9% (Table 11). The road was located to accommodate a park adjacent to the lake, and therefore a particularly

Table 9. Costs, Ground-Skidding System, Pilot Point: Summary

	Caterpillar D4H	FMC 210CA	KMC 2400CA
Total volume scaled (m^3)	4312	1963	2401
Falling ($/m^3$)	2.94	2.94	2.94
Skidding ($/m^3$)	5.81	8.79	8.88
Loading/bucking[a] ($/m^3$)	6.56	6.56	6.56
Total cost on the truck ($/m^3$)	15.31	18.29	18.38

[a] The loader was not on-site during the last two weeks of harvesting. Self-loading trucks were used. Cost assumes loader used throughout the study.

Table 10. Results of Site-Disturbance Surveys Conducted by BCMOF, Robson Ridge

Harvesting system	Season	Patch	Gross area (ha)	Disturbance: Haul road (%)	Landing (%)	Total road and landing (%)	Skid road (%)	Skid trail and ruts (%)	Total skidding (%)
Ground-skidding[a]	Summer	19	1.8	10.7	0.0	10.7	10.7	3.4	14.1
		31	2.5	42.7	0.0	42.7	2.6	4.2	6.8
		68	2.4	20.3	1.2	21.5	14.1	1.7	15.8
	Winter	42	3.5	5.7	0.0	5.7	6.5	1.2	7.7
		44	3.7	4.9	1.6	6.5	8.8	2.7	11.5
		76	2.7	14.5	0.0	14.5	9.6	2.2	11.8
Cable yarding[b]	Summer	24	3.5	8.6	7.9	16.5			
		100	2.7	17.5	1.6	19.1		Not surveyed	
		101	1.3	14.2	0.0	14.2			
	Winter	50	4.0	10.2	0.8	11.0			
		52	3.3	7.8	2.4	10.2		Not surveyed	
		66	2.8	3.2	1.0	4.2			
Development area			343	8.0[c]					

[a] JD 550 crawler-tractor and Cat 518 rubber-tired skidder. [b] Rosedale Ecologger II. [c] Estimate provided by A. Skakun, BCMOF, Resource Officer, Small Business, August 18, 1994. Includes haul roads only; forwarding trails have not yet been established.

Table 11. Results of Site-Disturbance Surveys Conducted by BCMOF, Pilot Point

Harvesting system	Patch	Gross area (ha)	Disturbance: Haul road[a] (%)	Landing (%)	Total road and landing (%)	Skid road (%)	Skid trail and ruts (%)	Total skidding (%)
Development area		82	7.7	1.3	9.0			
Caterpillar D4H	A	1.5				0.0	11.9	11.9
	B	1.3				0.0	6.1	6.1
	C	1.2				2.9	2.2	5.1
	D	0.9				0.0	4.0	4.0
	E	0.8				0.0	17.0	17.0
	F	0.8				0.0	11.1	11.1
	G	0.8				0.0	14.6	14.6
	I	1.2				0.0	7.3	7.3
	U	0.9				0.0	17.1	17.1
					Average	0.3	10.1	10.4
FMC 210CA	J	1.4				0.0	4.5	4.5
	K	1.2				0.0	11.2	11.2
	L	1.0				0.0	16.5	16.5
	M	1.3				0.0	8.4	8.4
KMC 2400CA	J	1.4				0.0	4.5	4.5
	Q	1.3				0.0	7.6	7.6
	R	1.8				0.0	5.8	5.8
	S	1.2				0.0	2.9	2.9
	T	0.7				0.0	5.6	5.6
					Average	0.0	7.8	7.8

[a] Forwarding trails are included.

tight switchback resulted in a larger road occupancy than ideal. The PHSP did not identify levels of disturbance for main haul roads; however, the PHSP allowed disturbance for spur roads, landings, and forwarding trails totalling 11.5%, more than the value resulting from the surveys.

Within-patch skidding disturbance ranged from a low of 2.9% to a high of 17.1% (Table 11). Constructed skid roads were present in only one patch, Patch C, but it also had one of the lowest levels of disturbance. Because Patch E was steep with rocky knolls, the skid trails funnelling into the landing created heavy disturbance adjacent to it (17%). Patch U, with the highest disturbance (17.1%), was the steepest of the Pilot Point patches; scalping was the most common disturbance here. Patch L also had a high level of disturbance (16.5%); this area had broken terrain with knolls, contributing to high levels of scalping disturbance. Overall, the Caterpillar D4H had slightly higher site disturbance than the FMC/KMC system. The target level for skid trails identified in the PHSP was 6%, and was achieved in seven of the patches. The survey results were highly variable, and the average disturbance for each machine system was higher than the target PHSP level.

DISCUSSION

Ground-Skidding System at Robson Ridge

In these trials, landings were not always adjacent to, or located near, the harvested patches, resulting in a wide range of maximum (200- to 500-m) and average (125- to 350-m) skidding distances. In some cases, such as Patches 19 and 31, the haul road was used for skidding. Although rubber-tired skidders may achieve increased travel speed on haul roads, crawler-tractors cannot. Crawler-tractors generally require average skidding distances of less than 300 m to be cost effective (McMorland 1980).

In the ground-skidding patches, two landings identified on the logging plan were relocated by the contractor because the original locations required too much excavation due to steep slopes and rock. In two other cases, landings were considered unnecessary by the contractor, while on one patch an additional landing was built.

Patch 68 was harvested by skidding uphill to a landing because restrictions on a lower haul road made this landing essential in order to continue working (Figure 8). The landing was very small and delays occurred due to congestion and difficulties associated with sorting, loading, and bucking. This landing was used again by the same contractor in the winter harvest to access another patch; during the second usage the contractor increased the landing area.

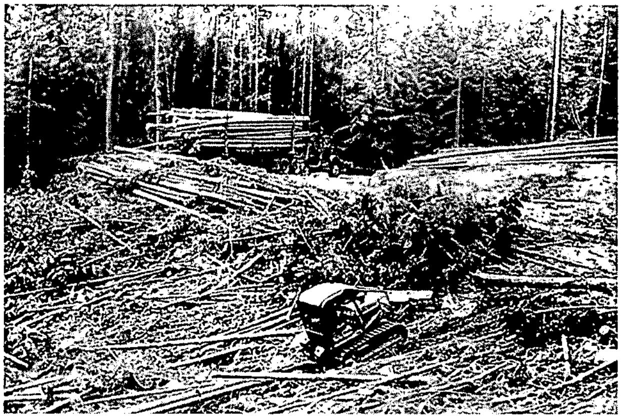


Figure 8. John Deere 550 crawler-tractor at Robson Ridge, adverse skid to landing.

The narrow configuration and road frontage of some patches, combined with the 30-50% slopes, resulted in skid roads with steep grades. Under wet fall and winter thawing conditions, adverse skidding became difficult, with increased risk of detrimental site disturbance, and skidding was halted for several shifts.

Generally, the skidding network consisted of constructed skid roads on steep and moderately steep slopes, and dispersed skidding or skid trails on gentle slopes and benches. In winter the crawler-tractor did most of the off-trail skidding while the rubber-tired skidder worked on constructed skid roads. During harvesting, several examples were observed where modifications to skid-road locations might have improved skidding, but overall the skidding network served satisfactorily.

Cable-Yarding System at Robson Ridge

Yarding distances within the patches were limited by deflection and machine capability, but not by the small patch clearcut method itself. Maximum yarding distances varied from 170 to 270 m while average yarding distances ranged from 80 to 130 m. Generally, longer distances led to longer cycle times; but, where deflection was satisfactory, inhaul and outhaul times were minor portions of the total cycle time.

Lack of adequate deflection was a problem on two patches, but only a few yarding roads were affected. The operators adapted to the poor deflection by yarding lighter loads, slowing inhaul speed, or re-rigging backspar trees at greater heights. The available data were not sufficient to reliably estimate increases in cycle times or effects on productivity due to poor deflection.

Delays in production also resulted when machines and supplies moved to the next patch. Distances between consecutively harvested patches varied from 0.5 to 5.8 km. In a conventional harvesting block, distances between landings on the same block (and road system) would be about 150 m. In the study, average patch size was 2.7 ha; therefore, if one landing had serviced each patch, the number of moves would have been similar to larger sized clearcuts. However, if patch size was 1 ha, more machine moves would be necessary; moving time would then become a significantly greater portion of total time, particularly at distances of more than several kilometres.

On two patches, unplanned landings were established to overcome difficulties in yarding and depositing logs on the original landings. Extra time was required to set up on these additional landings, and additional site disturbance occurred. Alternative road layouts or patch boundaries may have avoided these problems, but the effects of any changes on the unlogged patches would also have to be considered. The analysis of second and third entries is beyond the scope of this report.

The most common delay for the yarder was waiting for the loader to remove logs from around the yarder. These delays were especially noticeable on Patch 101, which had a very small landing. The loader had poor access to the unhooking area because the yarder landed the logs on the road fill slope. Also, when the loader was loading trucks, the yarder continued work. Decking and unhooking became slower and more difficult. On occasion, the yarder had to halt production when the pile became unsafe for unhooking turns.

Some deflection problems could have been avoided by running more deflection lines during field layout. Landing locations and/or patch boundaries may have been modified as a result. When assessing deflection, it is also important to consider where on the landing the yarder will actually be positioned, especially on areas with marginal deflection. On Patch 24, an existing right-of-way landing, located 25 m above a slope break, was used for yarding. Inadequate deflection at the slope break caused yarding difficulties and site disturbance. Better planning of landing location early in the development and more deflection lines would have resolved this problem.

The contractor situated landings above the road to improve deflection and to provide the loader with better access to the unhooking area. On Patch 66, an existing skid road was extended to place the yarder on a pad above the haul road. The haul road was widened to serve as the decking, processing, and loading area, and some logs were decked on the moderately sloped cutbank. The patch above (Patch 68) was harvested by ground skidding in the summer as part of this study; the cable-yarding contractor had the foresight to mark stumps needed for guylines during his winter harvesting. The skidding crew cut those stumps high and left them undisturbed. Where adequate stumps were sparse, the contractor used the rubber-tired skidder and crawler-tractor as anchors.

Although Patches 24 and 100 each required an extra landing, the area of the extra landing was small. In both instances the contractor utilized minor benches and the road surface for the landing's working surface. For example on Patch 100, the ditch and sloped cutbank were used to deck logs, so additional excavation was minimal. However, the extra landing for Patch 100 could have been eliminated by amending the patch boundary slightly. A similar modification to the boundary of Patch 24 would also have eliminated the need for this extra landing. The important point to recognize is that such adjustments can be made only in the layout phase. If deflection problems are not recognized and corrected during layout, they usually become obvious only after the site is felled, and the only alternative available may then be to create another landing.

Ground-Skidding System at Pilot Point

Pre-marking the leave trees may not have been necessary if the contractor had had specific instructions to follow. Faller selection of leave trees could have improved stem alignment for skidding, and eliminated some of the site disturbance and skidding problems that resulted in avoiding the leave trees. In Patch M, marked leave trees were located on ideal sites for skid trails, making skidding more difficult and resulting in damage to the leave trees (Figure 9). The option existed to substitute trees, but this was not clearly understood by the contractor, or agreement with the BCMOF supervisor was not reached.

The patch clearcuts harvested by the KMC were generally steeper than those skidded by the D4H and this likely

Figure 9. Caterpillar D4H at Pilot Point manoeuvring around leave trees.

reduced the KMC's productivity. Patch J, skidded by both the FMC and the KMC, was very difficult to harvest. The contractor felt that cable yarding would have been a better, and safer, method to use on this patch. While Patches Q and T could be safely harvested by the KMC, the machine was unable to climb some steep areas and, instead, travelled around the block boundary to reach parts of the patch. Patch R was less steep than the others, but it had considerable adverse skidding which resulted in increased site disturbance. Patch R could have been yarded successfully with a cable system.

In several instances, forwarding trails were not optimal for skidding. At Patch B, the forwarding trail entered the patch at an acute angle. Logs had to be turned through a large angle to get on the trail, resulting in damage to edge trees. At Patch I, an offset of the trail by about 20 m would have avoided a rocky knoll with the associated adverse grade and site disturbance. The entry of this trail into the block also was acute, and could have been improved. Again, the option for relocating this trail should have been discussed during a walk-through by the contractor and supervisor prior to harvest; depending on which patches were identified for future harvest, the trail may have been relocated.

The larger landings had sufficient room for the loader to perform its tasks. However, the smaller landings could not accommodate the machine. Because site occupancy by landings must be kept to a minimum, large landings must service many patches, or narrow roadside landings can be used for individual patches. The choice depends primarily on the need to sort logs.

Both skidding and hauling would have been improved if roads and forwarding trails had been constructed six months to a year in advance. The roads were very sensitive to moisture and became impassable when rain and wet snow occurred.

Productivities and Costs

The productivity of the equipment studied in this operation falls within other experiences monitored by FERIC. Productivities of 6-9 m^3/PMH for the John Deere 550 crawler-tractor and the Caterpillar 518 rubber-tired skidder are low. However, McMorland (1980) reported similar productivities of some small crawler-tractors within another study, with average piece size of 0.4-0.6 m^3. The productivity of the Rosedale Ecologger II cable yarder is somewhat less than the 20 and 24 m^3/PMH reported by Forrester (1993) for another small yarder, but moving time and other activities related to the specifics of the Robson Ridge operation can easily account for this. The productivity of the Caterpillar D4H, FMC 210CA and KMC 2400CA at Pilot Point fall within expectations as well. The results for the Pilot Point ground-skidding and Robson Ridge cable-yarding operations are conservative, and should be achievable by other contractors. However, the results from the Robson Ridge ground-skidding operation should be viewed with caution. Many contractors with older equipment keep a machine such as a loader or a spare skidder on site despite it having a low level of utilization. Determining its cost is difficult, and the calculated result can be unacceptably high. As well, piece size in this operation was the lowest, in some cases half that of the other operations.

The small yarders, such as the Ecologger or the Skylead, offer costs comparable with ground skidding in certain situations. However, during this study all of the patches harvested with the yarder were located near landings, and no secondary forwarding of the wood to a truck-loading location was necessary. When future patches are cable harvested, forwarding will be necessary to place the logs adjacent to the haul roads. As well, costing here was based on a used Ecologger, resulting in lower cost than for an equivalent new machine.

When the productivity of an operation does not provide enough volume to keep a loader busy, an option is to use self-loading logging trucks. These can be very effective and are in common use in some regions. In areas with narrow landings these trucks occupy the roadway and take longer to load than with an independent loader. Their use depends on good coordination of skidding and trucking if the skidding phase is to continue effectively. In the small patch system, the operational logistics must be well thought out with respect to number of sorts required, landing size, location, and access.

Site Disturbance

Site disturbance outside of the patches is due primarily to layout and patch selection and not specifically to the harvesting system. Attributing the road disturbance to patches, as was done at Robson Ridge, is not the most representative method and the Pilot Point approach is more suitable to this small patch layout method.

The conditions of the patch, i.e. slope, broken terrain, and adverse skidding, had a definite effect on site disturbance, as did the skidding pattern. The influence of machine type is less obvious because the high levels of disturbance in some patches could have been reduced with different skidding techniques. As well, preplanning rehabilitation of skid roads or excessively disturbed areas is now an option, and this would be a technique to meet site-disturbance levels.

Layout

Total-Chance Plan. Developing a total-chance plan, with roads, forwarding trails, and patches identified for all entries, is critical to success with this pattern of harvest. The first entry cannot compromise the ability of later entries to meet visual quality objectives or site-disturbance requirements. Because the small patch clearcut system involves distributing numerous patches throughout a landscape, road development for the first entry must be adequate to access entries for sixty or more years. The infrastructure for this type of harvest consists of roads and forwarding trails used in multiple entries, with skid roads and skid trails supplementing these on a single-entry basis. Although actual ground location of all patches and trails within the operating area may not be necessary, field layout must be adequate to ensure timber isolation does not occur. In very difficult terrain, in fact, location of all patches and forwarding trails may be essential. Not all of the forwarding trails and haul roads will be built in the first entry; time of construction will depend upon the location of patches for each entry. If some of the patches require a specific harvesting system (for example, cable yarding), these should be grouped within an entry for efficiency.

Roads, Landings, and Forwarding Trails. Roads and forwarding trails must be built to standards that will allow them to be stabilized after harvest and then reactivated for the next entry. In some cases, it may be advisable to design minimum width roads. Outward sloping surfaces on forwarding trails are unsafe for machine operators and will cause excessive residual damage on the downhill side. Tight corners will also cause skidding problems, particularly with tree-length stems. Each landing should be well constructed and stabilized between entries as well. A landing must service multiple patches over multiple entries, and its size must be minimized to meet site disturbance levels. In some cases, particularly where a processor could be used and sorting is not required, landings may not be necessary.

Flexibility in the location of the forwarding trails should be allowed, provided the decision is consultative between the contractor and supervisor. In some cases, some inefficiency in an early entry may be necessary to facilitate later entries. Communicating this information will improve the contractor's understanding and acceptance of the layout.

The angle at which a forwarding trail enters a small patch may be critical to efficient harvesting. Acute angles or a perpendicular entry in the middle of a rectangular patch will make both manual falling and skidding difficult. A variety of patch shapes should be considered; for example, diamond or teardrop shaped with the forwarding trail running through the main axis. The location of patches for subsequent entries must be tested against any first entry plan. The entry of the forwarding trail onto the landing must allow the wood to be brought in easily.

Cable Yarding. Two variables are key to productivity of any cable-yarding system: tree size and deflection. Obviously little can be done about tree size. However, deflection can be modified by placement of the yarder, location of patch boundaries, and height of backspar. The use of backspar trees rather than a mobile backspar can provide a better result in some instances because rigging height can be greater. At the Robson Ridge study area, deflection was poor in several patches. Deflection lines should be run from the point where the yarder will be positioned to provide accurate information. It is most desirable to use only one landing with each small patch because the move time for the yarder reduces productivity and the additional site disturbance can be prohibitive. In later entries, these landings may be re-used. In patches with long adverse grades, cable yarding is the best method.

Residual Trees. Increasingly, silvicultural prescriptions will include leaving trees to meet silvicultural or biodiversity objectives. These trees should be left in clumps, unless there is a strong reason for uniform distribution. Clumps improve safety conditions for workers and the efficiency of falling and skidding, and reduce damage to the residuals. If the criteria are supplied to the contractor, the workers can determine the most appropriate trees to retain without reducing harvesting efficiency.

CONCLUSIONS

In the Kootenay Lake and Arrow Forest Districts of southeastern British Columbia, harvest planning and selection of harvesting systems must be responsive to high recreation and tourist values, and the visually sensitive slopes. Intermediate slopes of 30 to 50% were targeted for a trial to assess harvesting with small patch clearcuts. The harvesting trial was funded in part by the BCMOF through its Alternative Silvicultural Systems Research Program and by the Forestry Practices component of the Canadian Forestry Service's Green Plan. Two study sites were chosen, one in Arrow Forest District on Robson Ridge and a second in Kootenay Lake Forest District at Pilot Point. At Robson Ridge, both ground skidding and cable yarding were used, in summer and winter seasons; at Pilot Point, low ground pressure skidders were used and only in the summer. FERIC monitored harvesting and the BCMOF conducted site-disturbance surveys.

At Robson Ridge, with the ground-skidding system in the summer, a John Deere 550 crawler-tractor produced 6.1 m^3/PMH, compared to 8.2 m^3/PMH for a Caterpillar 518 rubber-tired skidder. In the winter, productivities were 7.2 and 9.1 m^3/PMH respectively. The cable-yarding system, a Rosedale Ecologger II, produced 19.1

m^3/PMH and 17.8 m^3/PMH in the summer and winter trials respectively. At Pilot Point, a Caterpillar D4H custom skidder produced 16.5 m^3/PMH, while a KMC 2400CA produced 15.9 m^3/PMH, and an FMC 210CA 13.7 m^3/PMH.

The costs of the cable-yarding system at Robson Ridge and the low ground pressure equipment at Pilot Point were similar. At Robson Ridge the costs were $18 and $21/$m^3$, on the truck, for the cable yarding in summer and winter respectively. At Pilot Point the on-truck costs were $15/$m^3$ for the Caterpillar D4H; and $18/$m^3$ for both the FMC and KMC skidders. These figures are on the upper range of results for similar studies done by FERIC. The ground-skidding system at Robson Ridge was more costly, up to $30/$m^3$. The patches harvested by this system had long skidding distances, and piece size was very small. Also, the contractor's machine capacity exceeded the availability of operators and volume.

The main factors affecting productivity and cost were related to planning and layout: the location of the patches with respect to the landing; length of forwarding trail; forwarding trail alignment, both along the trail and at the entrance to the block; deflection; and slope (magnitude and adverse/favourable). Equipment utilization and season of operation also had an effect, especially on cost. The investment in a good system of roads and forwarding trails is essential. The majority of difficulties during harvest within the study areas related to layout and location of patch boundaries, landings, and forwarding trails or skid roads. Many of these problems could have been avoided by making only minor changes. Better communication concerning layout, supervision, and operations would improve the success of small patch clearcut harvesting in meeting economic and environmental objectives.

In planning a small patch clearcut, it is likely that roads and trails will constitute a greater proportion of the productive land area than when developing larger cutblocks. In preparing a plan for a small patch development area, the harvesting of all patches on the forwarding trails needs to be addressed, particularly where patch size is 1 ha or less. With cable-yarding systems, if forwarding the wood with ground-based equipment is necessary, it will add substantial cost to the harvest. Average skidding or yarding distances for individual patches will be more variable than averages for conventional clearcuts (depending on the proximity of the landing). This may impact on the productivity and cost for specific entries.

The site-disturbance surveys identified high road and landing disturbance at Robson Ridge, but this was due in part to the method of calculating the disturbance. Allocating the disturbance due to access and service structures (haul roads, landings, and forwarding trails) over the total harvestable area is a more realistic approach than on a patch-by-patch basis. The within-patch skidding disturbance on the patches harvested by the small crawler-tractor, high-track, and flexible-track skidders showed high variation within each skidder type. The lower levels of disturbance were at Pilot Point, with the lowest for the KMC skidder. This lower level of disturbance must be viewed as a sample only; the additional cost of harvesting with this equipment must also be considered.

REFERENCES

Braumandl, T. F.; Curran, M.P. (editors). 1992. *Field Guide for Site Identification and Interpretation for the Nelson Forest Region, A*. Research Branch, British Columbia Ministry of Forests, Victoria. 311pp.

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

British Columbia Ministry of Forests. 1993. *Soil Conservation Guidelines for Timber Harvesting - Interior British Columbia*. Victoria. 5pp.

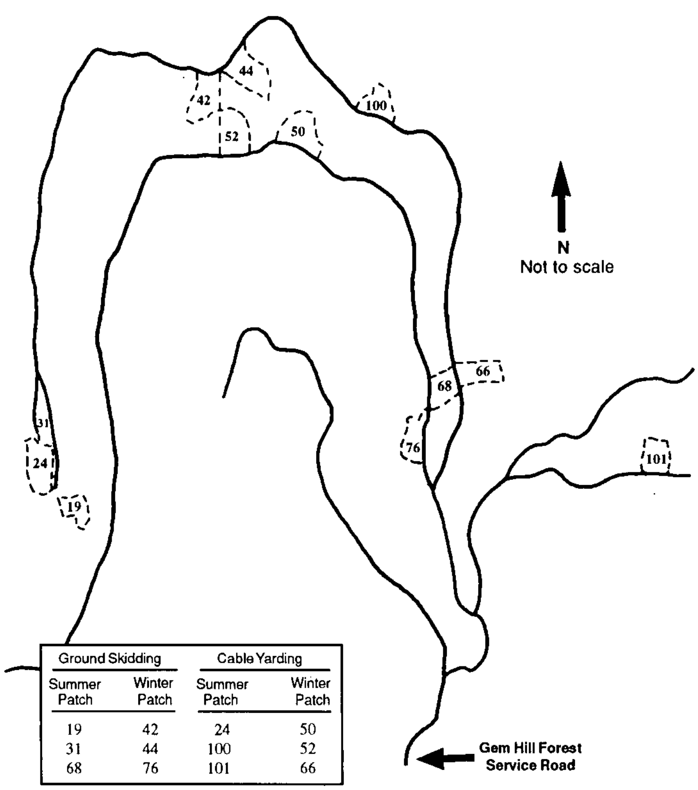
Curran, M.; Thompson, S. 1991. *Measuring Soil Disturbance Following Timber Harvesting*. British Columbia Ministry of Forests, Victoria. Land Management Handbook, Field Guide Insert 5. 25pp.

Forrester, Patrick D. 1993. *Observations of Two Skylead C40 Cable Yarders*. FERIC, Vancouver. Technical Note TN-201. 8pp.

McMorland, Bruce. 1980. *Skidding with Small Crawler-Tractors*. FERIC, Vancouver. Technical Report. TR-37. 89pp.

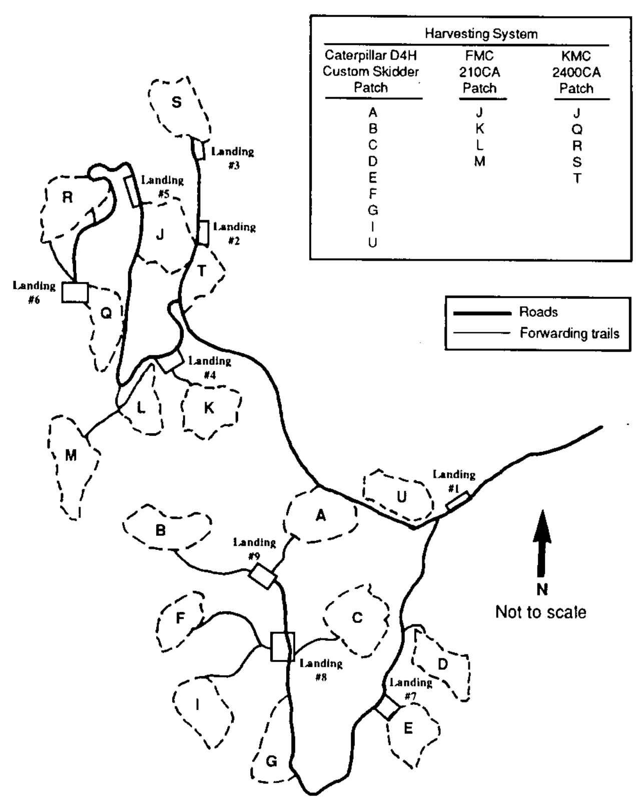
APPENDIX I

Layout of Patch Clearcuts at Robson Ridge and Pilot Point Study Sites



Ground Skidding		Cable Yarding	
Summer Patch	Winter Patch	Summer Patch	Winter Patch
19	42	24	50
31	44	100	52
68	76	101	66

Figure I-A. Layout of patch clearcuts at Robson Ridge study site.



Harvesting System		
Caterpillar D4H Custom Skidder Patch	FMC 210CA Patch	KMC 2400CA Patch
A	J	J
B	K	Q
C	L	R
D	M	S
E		T
F		
G		
I		
U		

Figure I-B. Layout of patch clearcuts at Pilot Point study site.

APPENDIX II

Costing: Ground-Skidding System at Robson Ridge

Hourly Machine Costs

	John Deere 550 crawler-tractor	Caterpillar 518 rubber-tired line skidder	Caterpillar 966 front-end loader
OWNERSHIP COSTS			
Total purchase price (P) $	122 165	140 000	250 000
Expected life (Y) y	6	5	8
Expected life (H) h	9 600	8 000	12 800
Scheduled hours per year (h)=(H/Y) h	1 600	1 600	1 600
Salvage value as % of P(s) %	20	20	20
Interest rate (Int) %	12.0	12.0	12.0
Insurance rate (Ins) %	2.0	2.0	2.0
Salvage value (S)=((P•s/100) $	24 433	28 000	50 000
Average investment (AVI)=((P+S)/2) $	73 299	84 000	150 000
Loss in resale value ((P-S)/H) $/h	10.18	14.00	15.63
Interest ((Int•AVI)/h) $/h	5.50	6.30	11.25
Insurance ((Ins•AVI)/h) $/h	0.92	1.05	1.88
Total ownership costs (OW) $/h	16.60	21.35	28.76
OPERATING COSTS			
Wire rope (wc) $	2 295	2 295	
Wire rope (wh) h	1 600	1 600	
Fuel consumption (F) L/h	14.0	16.0	16.0
Fuel (fc) $/L	0.38	0.38	0.38
Lube and oil as % of fuel (fp) %	10	10	10
Annual tire consumption (t) no.		4.0	1.0
Tire replacement (tc) $		2 500	3 500
Track and undercarriage replacement (Tc) $	7 183		
Track and undercarriage life (Th) h	4 000		
Annual repair and maintenance[a] (Rp) $	16 289	22 400	25 000
Wire rope (wc/wh) $/h	1.43	1.43	
Fuel (F•fc) $/h	5.32	6.08	6.08
Lube and oil ((fp/100)•(F•fc)) $/h	0.53	0.61	0.61
Tires ((t•tc)/h) $/h		6.25	2.19
Track and undercarriage (Tc/Th) $/h	1.80		
Repair and maintenance (RP/h) $/h	10.18	14.00	15.63
Total operating costs (OP) $/h	19.26	28.37	24.50
TOTAL OWNERSHIP AND OPERATING COSTS[b] (OW+OP) $/h	35.86	49.72	53.27

[a] Annual costs for repairs and maintenance were estimated as a percentage of purchase price spread over expected life.
[b] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include labour, supervision, profit and overhead, and are not the actual costs of the contractor or company studied.

Total Labour Costs

	Wages[a] ($/h)	Wages[a] ($/day)	Summer Total time (h)	Summer Total cost ($)	Winter Total time (h)	Winter Total cost ($)
Loader operator	27.03	-	294	7 947	306	8 271
Crawler-tractor operator	25.06	-	250	6 265	232	5 814
Skidder operator	25.37	-	148	3 755	189	4 795
Bucker	27.03	-	235	6 352	243	6 568
Saw rental	-	18.00		529		547
Faller	42.88	-	296	12 692	410	17 581
Saw rental	-	18.00		666		923
Digger	23.98	-			108	2 590
Total				38 206		47 089

[a] Wage includes 35% fringe benefits.

Total Machine Costs

	Cost ($/h)	Summer Total time (h)	Summer Total cost ($)	Winter Total time (h)	Winter Total cost ($)
John Deere 550 crawler-tractor	35.86	327	11 726	359	12 874
Caterpillar 518 rubber-tired line skidder	49.72	247	12 281	275	13 673
Caterpillar 966 front-end loader	53.27	294	15 661	306	16 301
Total			39 668		42 847

APPENDIX III

Costing: Cable-Yarding System at Robson Ridge

Hourly Machine Costs

	Maki II carriage	Ecologger (used)	Skylead Model 8000 yarder&skidder	Caterpillar 518 line skidder (used)	Dresser TD 15 E line skidder (used)	Caterpillar 215BSA loader
OWNERSHIP COSTS						
Total purchase price (P) $	44 000	65 000	153 229	50 665	40 000	200 000
Expected life (Y) y	5	5	10	4	4	7
Expected life (H) h	8 000	8 000	16 000	6 400	6 400	11 200
Scheduled hours per year (h)=(H/Y) h	1 600	1 600	1 600	1 600	1 600	1 600
Salvage value as % of P (s) %	20	20	20	20	20	20
Interest rate (Int) %	12.0	12.0	12.0	12.0	12.0	12.0
Insurance rate (Ins) %	2.0	2.0	2.0	2.0	2.0	2.0
Salvage value (S)=((P•s/100) $	8 800	13 000	30 646	10 133	8 000	40 000
Average investment (AVI)=((P+S)/2) $	26 400	39 000	91 937	30 399	24 000	120 000
Loss in resale value ((P-S)/H) $/h	4.40	6.50	7.83	6.33	5.00	14.29
Interest ((Int•AVI)/h) $/h	1.98	2.93	6.80	2.28	1.80	9.00
Insurance ((Ins•AVI)/h) $/h	0.33	0.49	1.13	0.38	0.30	1.50
Total ownership costs (OW) $/h	6.71	9.92	15.71	8.99	7.10	24.79
OPERATING COSTS						
Wire rope (wc) $		8 000	8 000	2 295	2 295	
Wire rope life (wh) h		1 600	1 600	1 600	1 600	
Rigging and radio (rc) $		5 250	5 250			
Rigging and radio life (rh) h		2 400	2 400			
Fuel consumption (F) L/h	0.9	8.5	8.5	10.0	10.0	11.0
Fuel (fc) $/L	0.38	0.38	0.38	0.38	0.38	0.38
Lube and oil as % of fuel (fp) %	10	10	10	10	10	10
Annual tire consumption (t) no.				4.0		
Tire replacement (tc) $				2 500		
Track and undercarriage replacement (Tc) $						20 000
Track and undercarriage life (Th) h						5 500
Annual repair and maintenance[a] (Rp) $	8 800	13 000	14 000	12 666	10 000	22 857
Wire rope (wc/wh) $/h		5.00	5.00	1.43	1.43	
Rigging and radio (rc/rh) $/h		2.19	2.19			
Fuel (F•fc) $/h	0.34	3.23	3.23	3.80	3.80	4.18
Lube and oil ((fp/100)•(F•fc)) $/h	0.03	0.32	0.32	0.38	0.38	0.42
Tires ((t•tc)/h) $/h				6.25		
Track and undercarriage (Tc/Th) $/h						3.64
Repair and maintenance (Rp/h) $/h	5.50	8.13	8.75	7.92	6.25	14.29
Total operating cost (OP) $/h	5.88	18.87	19.49	19.78	11.86	22.52
TOTAL OWNERSHIP AND OPERATING COSTS[b] (OW+OP) $/h	12.59	28.78	35.20	28.77	18.96	47.32

[a] Annual cost for repairs and maintenance were estimated as a percentage of purchase price spread over expected life.

[b] These costs are based on FERIC's standard costing methodology for determining ownership and operating costs. These costs do not include labour, supervision, profit and overhead, and are not the actual cost of the contractor or company studied.

Total Labour Costs

	Wages[a] ($/h)	Wages[a] ($/day)	Summer Total time (h)	Summer Total cost ($)	Winter Total time (h)	Winter Total cost ($)
Loader operator	27.03	-	276	7 460	288	7 785
Yarder operator	27.03	-	264	7 136	299	8 082
Bucker	27.03	-	270	7 298	280	7 568
Saw rental	-	18.00		608		630
Choker setter	23.98	-	260	6 235	316	7 578
Faller	42.88	-	194	8 319	268	11 492
Saw rental	-	18.00		436		603
Digger	23.98	-			268	6 427
Total				37 492		50 165

[a] Wage includes 35% fringe benefits.

Total Machine Costs

	Cost ($/h)	Summer Total time (h)	Summer Total cost ($)	Winter Total time (h)	Winter Total cost ($)
Ecologger II	41.37	264	10 922	299	12 370
Caterpillar 215 BSA grapple tracked loader	47.32	276	13 060	288	13 628
Caterpillar 518 rubber-tired skidder	28.77	264	7 595	299	8 602
International Dresser TD 15E crawler-tractor	18.96	264	5 005	299	5 669
Total			36 582		40 269

APPENDIX IV

Costing: Ground-Skidding System at Pilot Point

Hourly Machine Costs

	Caterpillar D4H custom skidder	FMC 210CA line skidder (rebuilt)	KMC 2400CA line skidder	Caterpillar 966 front–end loader
OWNERSHIP COSTS				
Total purchase price (P) $	200 165	150 165	240 165	250 000
Expected life (Y) y	6	5	6	8
Expected life (H) h	9 600	8 000	9 600	12 800
Scheduled hours per year (h)=(H/Y) h	1 600	1 600	1 600	1 600
Salvage value as % of P (s) %	20	20	20	20
Interest rate (Int) %	12.0	12.0	12.0	12.0
Insurance rate (Ins) %	2.0	2.0	2.0	2.0
Salvage value (S)=((P•s/100) $	40 033	30 033	48 033	50 000
Average investment (AVI)=((P+S)/2) $	120 099	90 099	144 099	150 000
Loss in resale value ((P-S)/H) $/h	16.68	15.02	20.01	15.63
Interest ((Int•AVI)/h) $/h	9.01	6.76	10.81	11.25
Insurance ((Ins•AVI)/h) $/h	1.50	1.13	1.80	1.88
Total ownership costs (OW) $/h	27.19	15.02	20.01	15.63
OPERATING COSTS				
Wire rope (wc) $	2 295	2 295	2 295	
Wire rope life (wh) h	1 600	1 600	1 600	
Fuel consumption (F) L/h	16.0	20.0	20.0	16.0
Fuel (fc) $/h	0.38	0.38	0.38	0.38
Lube and oil as % of fuel (fp) %	10	10	10	10
Annual tire consumption (t) no.				1.0
Tire replacement (tc) $				3 500
Track and undercarriage replacement (Tc) $	20 000	88 200	88 200	
Track and undercarriage life (Th) h	10 000	8 000	8 000	
Annual repair and maintenance[a] (Rp/h) $/h	26 689	24 026	28 000	25 000
Wire rope (wc/wh) $/h	1.43	1.43	1.43	
Fuel (F•fc) $/h	6.08	7.60	7.60	6.08
Lube and oil ((fp/100)•(F•fc)) $/h	0.61	0.76	0.76	0.61
Tires ((r•tc)/h) $/h				2.19
Track and undercarriage (Tc/Th) $/h	2.00	11.03	11.03	15.63
Repair and maintenance (Rp/h) $/h	16.68	15.02	17.50	15.63
Total operating costs (OP) $/h	26.80	35.84	38.32	24.50
TOTAL OWNERSHIP AND OPERATING COSTS[b] (OW+OP) $/h	53.99	58.75	70.94	53.26

[a] Annual costs for repairs and maintenance were estimated as a percentage of purchase spread over expected life.
[b] These costs are based on FERIC's standard costing methodolgy for determining machine ownership and operating costs. These costs do not include supervision, profit and overhead, and are not the actual costs of the contractor or company studied.

Total Labour Costs

	Wages[a] ($/h)	Wages[a] ($/day)	Total time[b] (h)	Total cost ($)
Loader operator	27.03	-	398	10 758
Caterpillar D4H operator	25.06	-	309	7 744
FMC/KMC operator	25.73	-	438	11 270
Bucker	27.03	-	589	15 921
Saw rental	-	18.00		1 325
Faller	42.88	-	565	24 227
Saw rental	-	18.00		1 271
Total				72 530

[a] Wage includes 35% fringe benefits.
[b] Does not include time when machine is idle and operator not on site, or when constructing skidding or forwarding trails.

Total Machine Costs

	Cost ($/h)	Total time[a] (h)	Total cost ($)
Caterpillar D4H custom skidder	53.99	320	17 277
FMC 210CA flexible-track skidder	58.75	204	11 985
KMC 2400CA flexible-track skidder	70.94	223	15 820
Caterpillar 966 front-end loader	53.26	502	26 737
Total			71 819

[a] Does not include time when constructing forwarding trails.

The Forest Engineering Research Institute of Canada (FERIC) is a non-profit research and development organization funded jointly and equally through a partnership of the forest industry and the Government of Canada. It was formed in 1975 to conduct research and development aimed at improving the efficiency of operations relating to the harvesting and transportation of wood, and the growing of trees.

Membership in FERIC is open to any corporation, partnership, organization or individual engaged in the harvesting, transportation or use of wood in Canada. Most of the major Canadian forest companies are currently members of FERIC and account for more than 60% of the total wood harvest.

FERIC's engineers, foresters and technicians operate from two divisions, one in Montréal and the other in Vancouver. FERIC's program covers the engineering and human aspects of the harvesting, processing and transportation of forest products, the mechanization of silviculture and the specific problems associated with woodlot operations. Because of the nature of this program, FERIC's research is field-oriented and projects are carried out in close cooperation with woodlands personnel.

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