WOOD HARVESTING

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HARVESTING SENSITIVE SITES WITH A LONG-DISTANCE CABLEWAY SYSTEM: PRODUCTIVITY AND COSTS

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Abstract

In 1991 and 1993, the Forest Engineering Research Institute of Canada (FERIC) studied a long-distance cableway system operating on forest land administered by the Greater Vancouver Water District (GVWD) in southwestern British Columbia. The study provided harvesting productivity and cost information for a long-distance cableway system with 10-t payload capacity. Production functions were derived to predict system productivity and costs over a range of operating conditions.

Introduction

Long-distance cableway systems, also known as skyline cranes or cable cranes, have been used to harvest timber in the Coastal and Interior regions of British Columbia and the Pacific Northwest of the United States since the 1950s. Operations have been conducted using equipment, of various payload capacities, manufactured in central Europe. Several studies have documented productivities and operating characteristics for systems with payload capacities of 5 tonnes (t) and sled yarders in the 60-75 kW class (Cassetta 1966; Waelti 1976; Hensel and Johnson 1979). Observations of larger-capacity (10-t) systems, often required to harvest old-growth timber in coastal western North America, have been documented less formally (Gesner 1981; Robson 1992; Blackman 1987).

In the literature, observers have invariably concluded that long-distance cableway systems are well-suited to harvesting a portion of the timber supply on environmentally sensitive steep slopes where reduced road construction and minimal soil disturbance are desired. Although forest operations on such sites face increasingly stringent environmental constraints, these systems have yet to gain widespread acceptance in western North America. In British Columbia, for example, during the last 40 years usually no more than two or three such systems have been operating at one time. However, many forest operators continue to express interest in this harvesting alternative.

To provide its members with factual information about using long-distance cableway systems, the Forest Engineering Research Institute of Canada (FERIC) studied a 10-t capacity system operating on forest land administered by the Greater Vancouver Water District (GVWD) in southwestern British Columbia (Figure 1). Harvesting was monitored on two cutblocks: one in 1991 and another in 1993. The GVWD elected not to construct forest roads into the cutblocks, thereby ruling out conventional cable yarding (i.e. tower yarding) as an alternative system of harvesting. The objectives of the study were to supplement existing knowledge about long-distance cableways with information about the productivities and costs associated with a system having a 10-t payload capacity, and to develop models to predict productivities and costs over a range of operating conditions.

Overview of Long-Distance Cableway Systems

Long-distance cableway systems are a well-established technology for harvesting timber on steep terrain. The systems are used extensively in central Europe on sites where environmental constraints and/or physical barriers to roading preclude conventional tower yarding

Keywords: Harvesting, Sensitive sites, Steep slopes, Cable logging, Long-distance cable systems, Evaluation, Productivity, Costs, Wyssen W-200 sled yarder, British Columbia

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(Bennett 1992). The primary manufacturers of these systems are Wyssen Skyline-Cranes Co. Ltd. of Switzerland and Rudolf Gantner Inc. of Austria.

System components include a standing skyline, a sled yarder (also referred to as a sled winch), and a skyline carriage. Prior to use, the skyline is pre-tensioned with a set of tensioning clamps installed at the skyline's lower anchoring terminus. Headspars and intermediate supports are often installed to elevate the skyline over undulating terrain. In the standard configuration a single-drum sled yarder, equipped with a mainline, is positioned at an elevation above a cutblock. Logs are fully suspended by the carriage, and they travel, under gravity, to a landing located below the cutblock. The yarder's mainline, which is threaded through the carriage, retrieves the carriage and is used to yard laterally when the carriage is clamped to the skyline. Also, timber located below a landing can be yarded uphill.

A sled yarder can be winched, under its own power, up a slope, or broken down into components and then flown into position with a helicopter. The yarder is usually situated near the upper terminus of the skyline but is offset from the skyline itself. The yarder's mainline runs from the winch drum, through a block placed under or in lead with the skyline, and then down to the carriage. The yarder must be placed a minimum distance from the mainline lead block (i.e. 20 times the width of the winch drum) to ensure there is an adequate fleet angle for proper line spooling onto the drum.

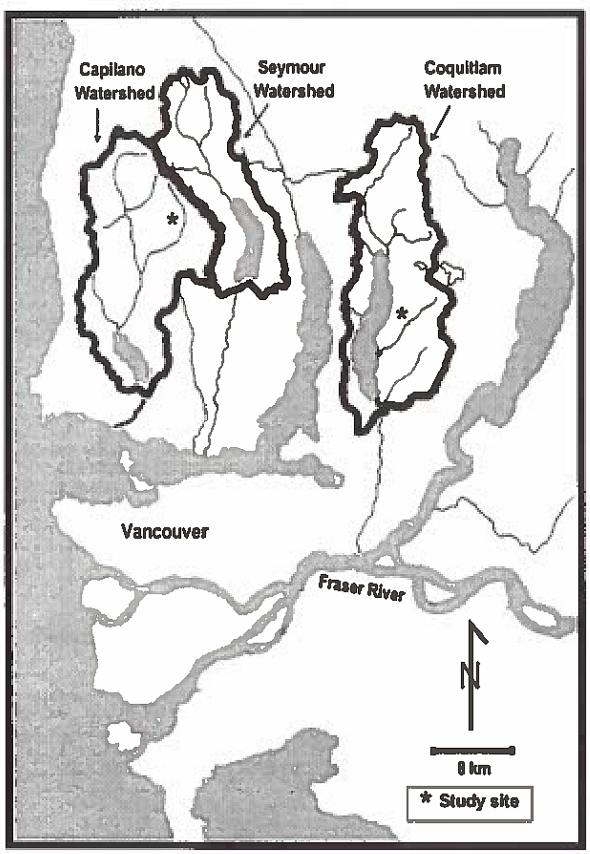

Figure 1. Location of study sites.

All-terrain systems are available that allow the yarder to be positioned at any elevation relative to the timber being harvested. However, these systems require an endless mainline arrangement and a slackpulling attachment for the carriage. This configuration is complicated, difficult to set up, and rarely used.

Further discussion about long-distance cableway system specifications and setup of the standard configuration can be found in the publications previously cited. Also, Bauernfried (1976) provides detailed information for planning, installing, and operating a cable crane.

Harvesting System

Hans Lee Timber Company Limited, of Delta, British Columbia, was awarded the harvesting contract for the cutblocks described in this report. A Wyssen W-200 model sled yarder, rated for 150 kW and weighing approximately 7500 kg, was used in the operations (Figure 2). The contractor had converted the yarder from a mechanical belt-drive to a hydrostatically driven winch drum arrangement. The system included a Wyssen carriage with payload capacity of 10-t (Figure 3). This carriage's skyline clamp is actuated by an hydraulic timing device. A special bullhook, weighing 45 kg, is connected to the end of the mainline and releases the skyline clamp as it is drawn up into the carriage. An air retarder, with a friction brake as a backup, controls the carriage's rate of descent as logs are transported to the landing under gravity. Skyline and mainline diameters were 46 mm and 22 mm respectively.

The crew complement for the yarding phase of the operation consisted of the sled yarder operator, a rigging slinger, and two chokersetters,[1] and a landing worker. A rubber-tired front-end loader cleared the landing, loaded logging trucks, and assisted with skyline installation and tensioning. The loader operator was also the operation's foreman and head rigger. The falling phase, not examined in this study, was subcontracted to a handfalling crew.

[1] A rigging slinger and chokersetters work within the cutblock to retrieve logs. The rigging slinger directs the chokersetters and controls the inhaul and outhaul functions via radio communications with the sled yarder operator.

Figure 2. Sled yarder positioned in standing timber above cutblock.

Figure 3. Wyssen carriage in Cutblock No. 1.

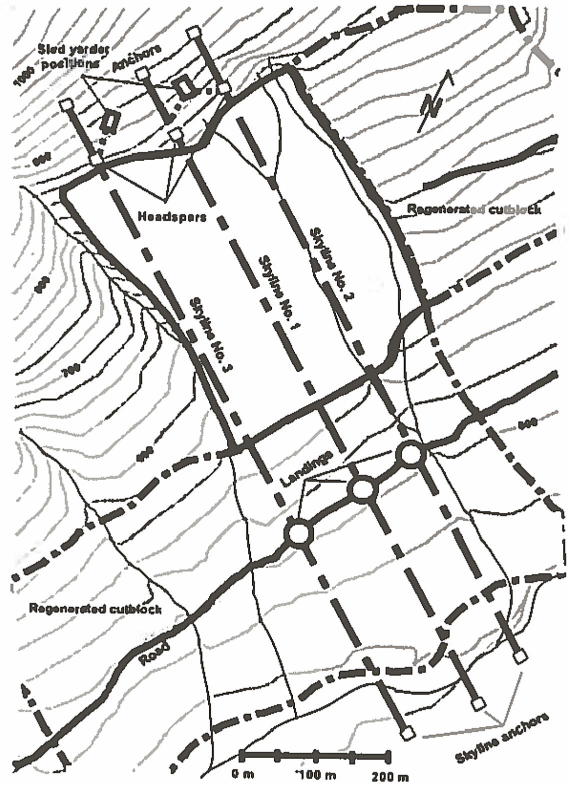

Figure 4. Skyline layout in Cutblock No. 1.

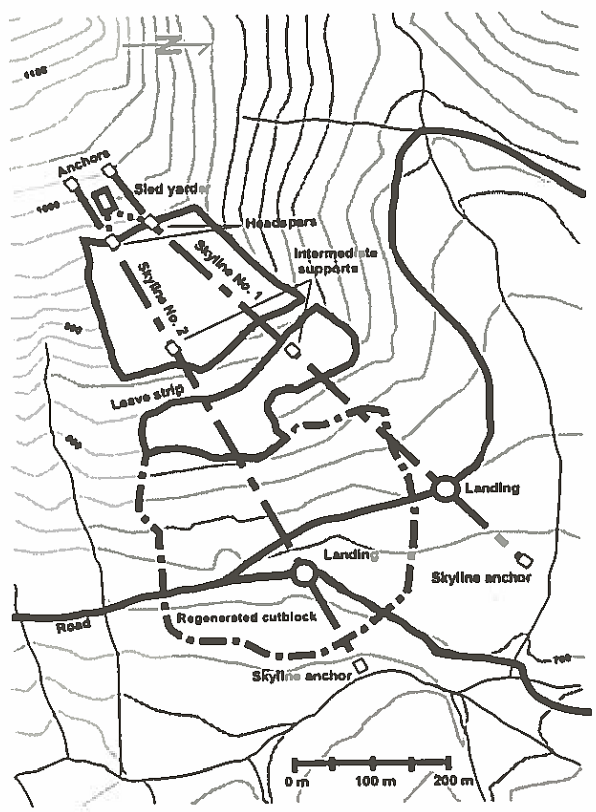

Figure 5. Skyline layout in Cutblock No. 2.

Site Descriptions

The study cutblocks (Figures 4 and 5) were located in two of the three major watersheds that provide water for the City of Vancouver and surrounding municipalities (Figure 1). The GVWD's primary management objective is to protect and enhance water quality in the watersheds. Regeneration cutting and stand treatments such as thinning were options only if the risk of slope instability following these activities was low.

Cutblock No. 1, situated in the Coquitlam watershed, is an 11.0-ha clearcut unit harvested in 1991 (Figure 4). The silviculture prescription was prepared when a former program for sustained yield harvesting was in effect and guided the GVWD's forest management activities.

Table 1. Timber volume harvested by cutblock and species.

Species	Cutblock No. 1 (m³)	Cutblock No. 1 (m³/ha)	Cutblock No. 1 (%)	Cutblock No. 2 (m³)	Cutblock No. 2 (m³/ha)	Cutblock No. 2 (%)
Amabilis fir	481	44	5	1640	269	34
Western hemlock	2060	187	22	2294	376	47
Western redcedar	5826	530	63	489	80	10
Yellow-cedar	533	48	6	427	70	9
Douglas-fir	354	32	4			
Total	9254	841	100	4850	795	100

Slope gradients in Cutblock No. 1 ranged from 60 to 80%. Construction of a road from an adjacent cutover into the block, to enable conventional tower yarding, was ruled out due to the gullied terrain. Three single-span skyline rig-ups were necessary (see Figure 4). The lengths of the skylines, from anchor to anchor, ranged from 1100 to 1200 m (slope distance). The maximum slope distance yarded was 700 m. Skyline Numbers 2 and 3 were positioned directly above gullies to facilitate extraction of timber straight up and out of the gullies. Logs were transported, fully-suspended, over a regenerated cutover to a landing below. The study block was clearcut. Harvested timber volumes by species are shown in Table 1. An average piece size of 1.4 m³ was calculated for the yarded logs.[2]

Cutblock No. 2, situated in the Capilano watershed, is a 6.1-ha unit harvested in 1993 (Figure 5). During this period the GVWD's silviculture prescriptions promoted development of "stable stands", i.e. stands that are the most resilient and resistant to destruction by fire, infestations by insects or other pests, or windthrow.[3] With this approach, western redcedar (*Thuja plicata*), yellow-cedar (*Chamaecyparis nootkatensis*), and Douglas-fir (*Pseudotsuga menziesii*) were the favoured tree species.

Slope gradients in Cutblock No. 2 ranged from 45 to 80%. Two skyline roads, each with one intermediate support, were required to harvest this cutblock (Figures 5 and 6). Skyline lengths, from anchor to anchor, of 1000-1100 m and a maximum slope yarding distance of 700 m were required. The long-distance cableway system enabled retention of forest cover on a band of terrain assessed with a moderate risk for slope instability. This leave strip separated the cutblock into upper and lower portions (Figures 5 and 7).

Figure 6. Intermediate support for Skyline No. 2 in Cutblock No. 2.

Figure 7. View of Cutblock No. 2 from lower terminus of Skyline No. 2. Tensioning clamps and carriage in foreground.

[2] Based on final scale data provided by the GVWD.
[3] Oikos Ecological Consultants, in *Assessment of Proposed 1992 Cutting Areas for Greater Vancouver Water District, Second Summary Report*, July 1992.

A partial cutting prescription was implemented in which 102 irregularly distributed trees, representing a total basal area of 49.2 m², were retained throughout the cutblock. Yellow-cedar trees accounted for 75% of this retained basal area. The side boundaries of the cutblock were also thinned to reduce the risk of windthrow. Harvested timber volumes by species are shown in Table 1. An average piece size of 1.5 m³ was calculated for the yarded logs.

Methods and Analyses

Detailed timing of yarding cycles, including delays, was done using a hand-held computer. The slope, yarding distance, lateral yarding distance, and number of logs were also recorded for each timed cycle. Logs from a sample of 46 timed cycles were scaled at the landing. At Cutblock No. 1, 215 cycles were detail-timed over a period of ten workdays. At Cutblock No. 2, 65 cycles were timed over a period of five workdays.

A series of activities, or time elements, was repeated in each harvesting cycle. Total cycle time is the sum of the time elements. For this study, the following time elements were defined.

Outhaul: Carriage travel, along the skyline, from the landing up to the harvest area.

Lateral out: Pulling the machine's mainline, laterally, from the carriage to the logs.

Hookup: Setting chokers on the logs.

Lateral in: Yarding the logs, laterally, until suspended under the skyline carriage.

Inhaul: Carriage and logs travel along the skyline down to the landing.

Unhook: Unhooking chokers at the landing.

The data were examined using multiple regression analysis. The desired dependent variable was *total delay-free cycle time*. For this study, *slope yarding distance*, *lateral yarding distance*, and *number of logs per cycle* were chosen as the independent variables. The relationship between total cycle time and each independent variable was estimated and a complete model, including all terms, was written for the data. The model was reduced, using the *elimination technique (backward stepwise)*, until every independent variable retained was significant. A 0.05 level of significance was used to test the significance of the relationship and the contribution each term made to the model.

Production functions were derived to predict system productivity in terms of volume of timber yarded per hour (m³/h) and cost per cubic metre ($/m³). Production functions are derived by adjusting predicted cycle times to reflect delays encountered in the harvesting system (Howard 1988). An average volume of logs yarded per cycle, obtained from the scaling data, was used to calculate the productivity and cost examples shown in this report.

One function estimates average productivity during scheduled yarding time (SYT). This productivity measure is needed to predict wood flow and schedule log hauling after the system has been installed and is operating routinely. SYT includes *delay-free cycle time* (i.e. productive cycle time) plus *delays within cycles*, time to transport fuel to the yarder and fuel-up, major mechanical delays, and service time for system components. *Delays within cycles* were various short mechanical and non-mechanical delays, of 0.5-h or less, occurring intermittently throughout the yarding cycles. These were measured during detailed timing. Fuel-up and service time, and major mechanical downtime (>0.5-h) were long delays determined from shift-level observations and contractor records.

A second production function accounts for system mobilization and demobilization time (MOB AND DEMOB). This enables predictions of overall harvesting cost for cutblocks with various sizes, shapes, and terrain conditions. MOB AND DEMOB time includes moving the sled yarder into position, installation and tensioning of the skyline, rig-up of any necessary intermediate supports, and the dismantling of these components following harvesting. First, an equation for total time (consisting of mobilization, scheduled yarding, and demobilization times) was developed using an approach similar to that in Howard and Dodic (1989). Cutblock timber volumes and an hourly system cost were then applied to the total time to calculate unit harvesting costs.

Hourly costs for the yarding and loading (Y&L) phases, calculated by FERIC (Appendix I), were combined and used to estimate unit harvesting costs in this report. The costs for Y&L are not examined separately because the front end loader and its operator were integral parts of the yarding system's installation and operation.

Results and Discussion

Results of Detailed Timing

A summary of the detailed-timing data is contained in Table 2. *Hookup* and *unhook* time accounted for 32% and 22% of productive cycle time, respectively. The

Table 2. Detailed-Timing Summary.

	Mean (min)	Min. (min)	Max. (min)	Std. dev. (min)	Obs. (no.)
Yarding cycle elements					
Outhaul	2.0	1.0	5.9	0.5	280
Lateral out	3.2	0.0	20.5	3.1	280
Hookup	5.8	0.8	22.2	3.3	280
Lateral in	1.3	0.2	16.4	1.3	280
Inhaul	1.9	1.0	4.8	0.6	280
Unhook	4.1	0.5	15.6	1.9	280
Total delay-free cycle time	18.4	7.6	43.2	6.6	280
Delays within cycles					
Mechanical, sled yarder	2.9	1.0	10.0	3.5	6
Mechanical, carriage	3.4	0.2	19.3	4.4	28
Lateral yarding hangup	5.2	1.0	10.0	3.8	4
Turn too heavy, re-hook	8.1	0.1	34.6	8.6	21
Other delays	5.8	0.8	20.0	4.5	38
Total delays (mean time/delay)	5.4	0.1	34.6	5.8	97
Total delays (mean time/cycle)	1.9	0.0	38.4	4.6	280
Yarding study parameters					
Slope yarding distance (m)	463	300	690	88	280
Lateral yarding distance (m)	24	0	80	21	280
Logs yarded/cycle (no.)	4.2	1	8	2	280
Volume yarded/cycle (m^3)	7.1	0.9	18.4	3.9	46

contractor's goal, reflected in the relatively large proportions of these elements, was to maximize payload without overstressing system components. Up to eight logs were transported per cycle; 4.2 was the average during the study. Chokers were routinely pre-set to reduce hookup time.

The lateral yarding elements (*lateral out* and *lateral in*) combined to account for 24% of productive cycle time. Usually, the maximum lateral yarding distance specified for this system operating in a clearcut, or a partial cut with widely spaced residuals, is 60 m. However a few instances of 80-m lateral yarding were encountered in this study. For distances >10 m, the crew used a chain-saw winch to pull the heavy bullhook and chokers laterally to the logs (Figure 8). Often, to accumulate the desired payload, logs were hooked up at several points in the lateral yarding progression.

Figure 8. Using chain-saw winch to pull bullhook, chokers, and mainline laterally.

Delays within cycles combined to account for a mean delay time of 1.9 min/cycle (and 7.7% of SYT). There were occasions when, after an initial pull by the yarder, the crew elected to reduce the payload by unhooking some logs or bucking an unusually large log. Delays typically resulted when large old-growth logs (some were >1.8 m in diameter) were not completely bucked during the falling phase. Although the yarder had sufficient power, the crew weighed the risk of breaking an intermediate support, headspar or skyline anchor, or overstressing the skyline in such situations. The carriage also caused several short delays during the study period. The mechanical linkage required regular lubrication, and was susceptible to inadvertent impacts from logs or branches.

Yarding Cycle Time

Equation 1 is the model for delay-free cycle time determined from multiple regression analysis. Significant linear relationships were found between cycle time and the independent variables: slope yarding distance, lateral yarding distance, and no. of logs/cycle.

[1] $CycleTime = 3.42641 + 0.011114\,(SlopeDist) + 0.110867\,(LatDist) + 1.69819\,(Logs/Cycle).$

$n = 280 \quad r^2 = 0.358 \quad S.E.E. = 5.299$

CycleTime = Total delay-free cycle time (min)

SlopeDist = Slope yarding distance (m)

LatDist = Lateral yarding distance (m)

Logs/Cycle = Logs yarded/cycle (no.)

n = Observations used in the analysis (no.)

r^2 = Coefficient of determination

S.E.E. = Standard error of estimate

Productivity

Equation 2 is the production function developed to estimate productivity during scheduled yarding time.

[2]

$$Productivity = (CycleVol \times 60) / \left[\frac{CycleTime}{1-(DelayTime)}\right].$$

Productivity = Measured in m^3/h. Adjusted to include delays (but excludes MOB AND DEMOB time)

CycleVol = Average volume yarded/cycle (m^3)

CycleTime = From Equation [1] (min)

DelayTime = ("within cycle" delays) + (fuel transport & fuel up) + (major mechanical delays & service)

= 0.077 + 0.070 + 0.100 = 0.247 (Expressed as fraction of SYT)

Delay-free cycle time equalled 75% of SYT. On average, production was curtailed for 5 h over 9 shifts (or 7% of SYT) to transport fuel to, and fuel-up, the yarder. Mechanical delays, >0.5-h duration, and service time accounted for approximately 10% of SYT. An average shift length of 8 h was assumed in these calculations.

Figure 9 shows the influence of slope yarding distance and lateral yarding distance on system productivity. For this analysis, *logs/cycle* and the average volume yarded/cycle were held constant at the study averages of 4.2 logs and 7.1 m^3 respectively (see Table 2). Productivity estimates are limited to the slope distance

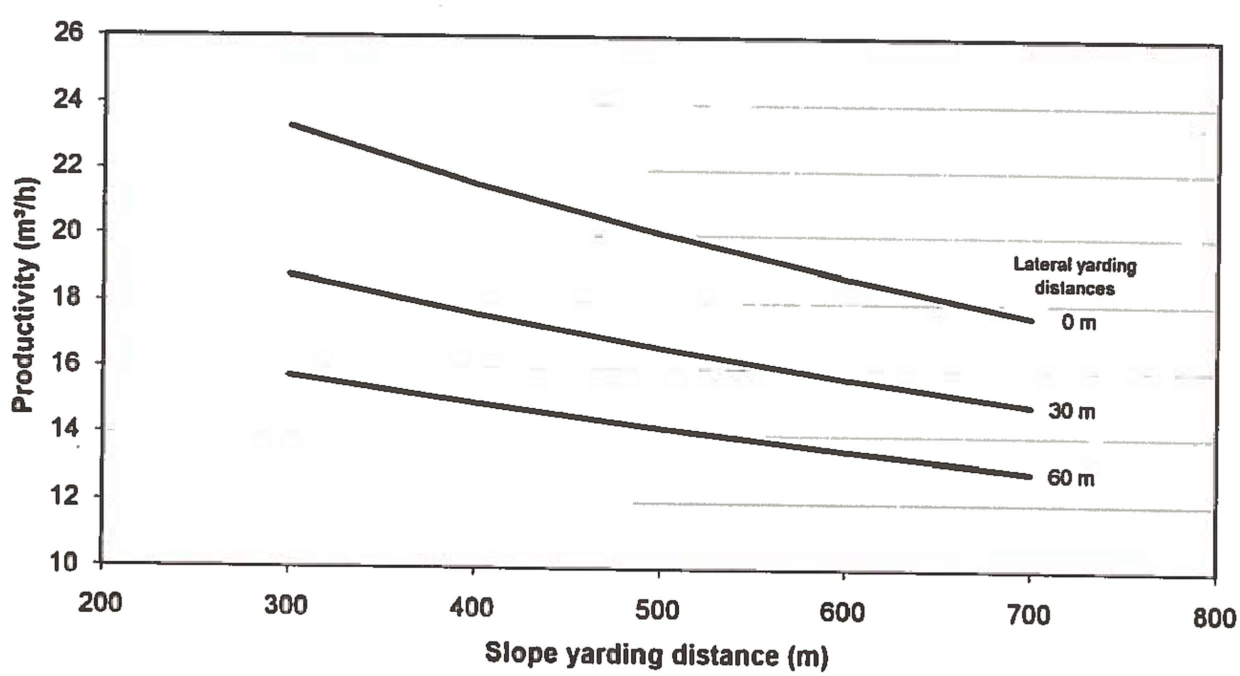

Figure 9. System productivity during scheduled yarding time (including delays).

range from which the data were derived; estimates using distances beyond this range are not valid.

Estimates of productivity, using the study cutblocks as examples, can be made given the average slope and lateral yarding distance in each case. For Cutblocks No. 1 and No. 2, average slope yarding distances were 500 and 450 m, and average lateral yarding distances were 25 and 30 m, respectively. Productivity and average number of cycles were calculated to be 17.1 m^3/h and 2.4 cycles/h in both instances.

The reader is reminded that these are average productivities, calculated over SYT, and include delays. During individual shifts much higher productivities may be experienced. For example, in Cutblocks No. 1 and No. 2, the maximum number of cycles/shift recorded was 32 and 40, respectively. (The lengths of these particular shifts were 8 and 9 h respectively). These correspond to productivities of 28 m^3/h and 32 m^3/h if the average volume yarded/cycle of 7.1 m^3 is applied.

Unit Yarding and Loading Cost

Unit yarding and loading cost, inclusive of system mobilization and demobilization costs, can vary substantially between cutblocks depending on sled yarder positioning, and the numbers of skylines and intermediate supports required in each case. Unit costs for Cutblocks No. 1 and No. 2 are calculated as examples. First, Equation 3 was developed and used to estimate total time for each cutblock.

[3]

$$TotalTime\,/\,Cutblock = \frac{CutblockVolume}{Productivity} + (sky\_rig)\times(skylines) + (int\_rig)\times(supports) + sledmove.$$

TotalTime / Cutblock = Total time to MOB AND DEMOB system and harvest setting (h)

CutblockVolume = Total timber volume in the cutblock (m^3)

Productivity = From Equation [2] (m^3/h)

Sky_rig = Time required to install, tension and dismantle one skyline (h)

Skylines = Skylines required to harvest the cutblock (no.)

int_rig = Time required to setup and dismantle one intermediate support (h)

supports = Intermediate supports required in the cutblock (no.)

sledmove = Time required to setup and dismantle the sled yarder (h)

For this analysis, the time required to setup and dismantle the sled yarder (*sledmove*) was estimated at 32 h. Forty hours were allocated to: rigging the headspar, pulling the skyline into position with the yarder and securing it at each anchor point, tensioning the skyline, and dismantling following harvest (*sky_rig*). Installation and dismantling of an intermediate support (*int_rig*) required 24 h. (The average time required to position the yarder for each new skyline corridor is included in *sky_rig*. Additional time should be allocated to this variable for cutblocks requiring more extensive travel of the yarder between corridors.)

The total timber volume, and an hourly system cost of $337.23, were then applied to the total time estimate for each cutblock to generate the charts shown in Figures 10 and 11. These charts illustrate the effects of slope yarding distance and lateral yarding distance on the unit Y&L cost for each cutblock. Average Y&L costs of $25.25/$m^3$ and $30.83/$m^3$ for Cutblocks No. 1 and No. 2 respectively were also calculated and superimposed on the charts for comparison.

Note, in these examples, the combination of average slope and lateral yarding distances produced similar productivity estimates for each cutblock (i.e. 17.1 m^3/h during SYT). However, the smaller volume of harvested timber and greater proportion of total time required for MOB AND DEMOB of all system components resulted in a higher unit cost estimate for Cutblock No. 2.

Because the study sites were situated in the GVWD watersheds, cutblock areas and harvested timber volumes were relatively small by standards in British Columbia. The proportion of total time allocated to dismantling the sled yarder increases for a smaller cutblock and this increases unit harvesting costs.

Another variable cost that is affected by cutblock size is unit cost of new road construction (amortized over the volume of timber harvested) in $/$m^3$ of timber harvested. High unit road construction costs, which are usually associated with the development of small areas for conventional tower yarding, were not incurred on these study sites because no new roads were required and existing main roads near the valley floor were used for landings.

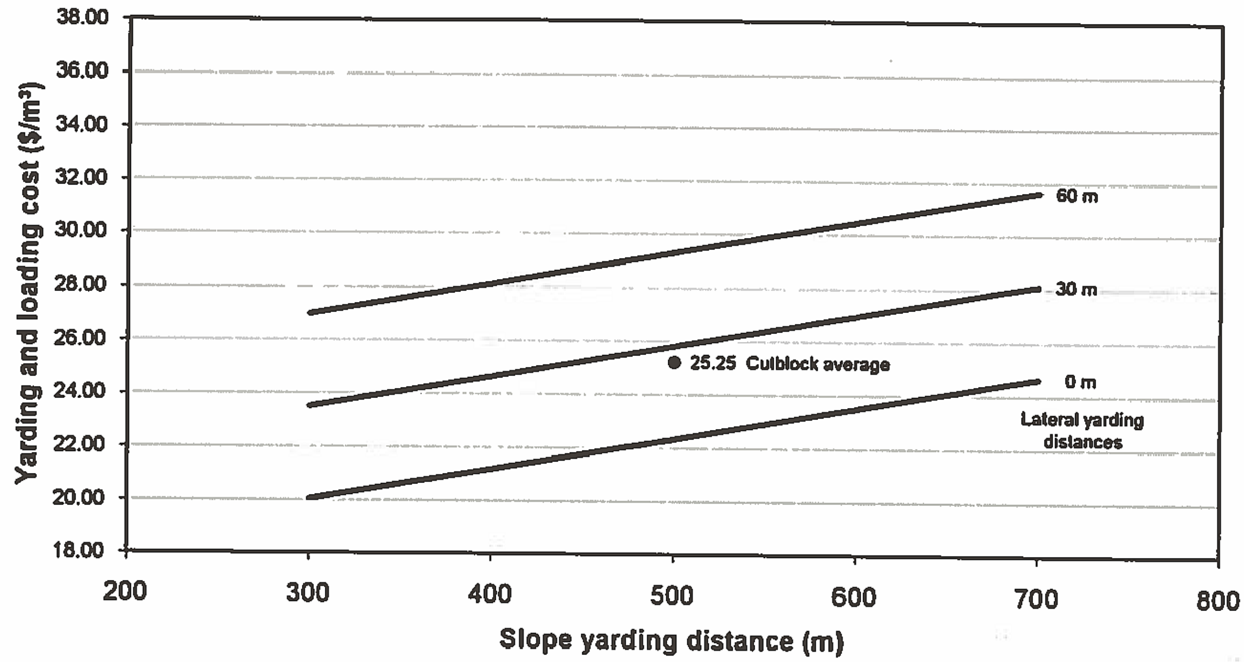

Figure 10. Unit yarding and loading cost for Cutblock No. 1.

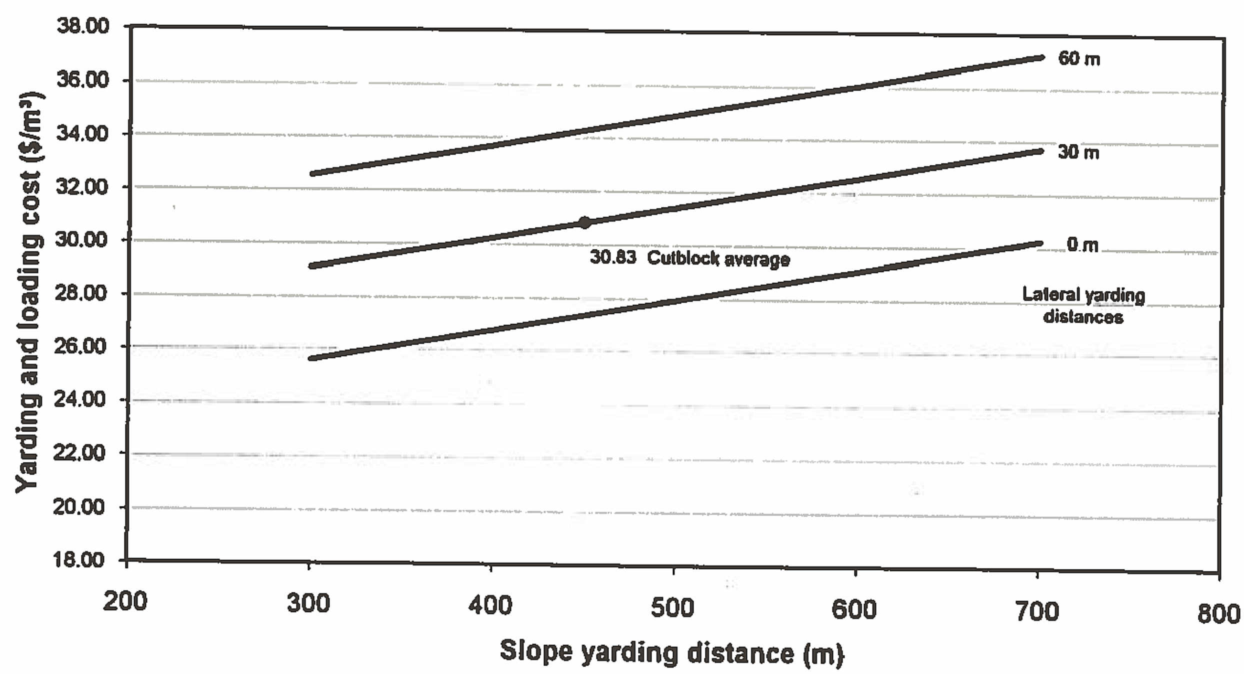

Figure 11. Unit yarding and loading cost for Cutblock No. 2.

Other Observations

The 10-t system was well matched to the large timber in the study cutblocks. Most logs were bucked to standard preferred lengths (e.g. 10.3 and 12.1 m) and handled with ease. However, many logs were bucked in 20-m lengths. To accommodate these, the intermediate support trees in Cutblock No. 2 were topped at heights of 33-39 m and the skyline support saddle was hung 24-27 m above ground level. Sometimes two chokers were set on one long log, in a bridle arrangement, to ensure adequate clearance and minimal soil disturbance as logs passed beneath the intermediate support.

Although the system's size was appropriate in this study, long-distance cableway systems having capacities of 5-8 t would be more efficient for those old-growth and second-growth forests with smaller trees. Benefits in ease of set-up and operation can be gained from using smaller-diameter skylines and mainlines, and lighter yarders.

The system had the capacity to lift large timber volumes per cycle directly up and out of gullies prior to transport under full suspension down the skyline (Figure 12). This practice prevented scouring of the gully wall and deposition of harvesting debris within the gully because logs were not dragged through these terrain features. Preserving gully integrity and water quality were especially important in Cutblock No.1's gullied terrain, and was achieved in this operation.

At both study sites, logs were transported over previously harvested and regenerated cutblocks to reach the landings. These regenerated areas were left intact other than sporadic damage to saplings located directly beneath the skyline. In Cutblock No. 2, the widely spaced residual trees were easily avoided during yarding and were not damaged.

Using a chain-saw winch to pull the rigging laterally influences the yarding sequence in a cutblock. The crew would begin at the top of a skyline road and work down, one side at a time. This practice minimized the time and effort required to carry the chain-saw winch within the cutblock.

Many different types of skyline carriages can be used with long-distance cableway systems. The carriage in this study was of intricate design, and required service throughout the operations. A delay, 24 seconds on average, occurred twice in each cycle for the hydraulic timing device to set the skyline clamp and allow the bullhook to descend to the ground. When the empty carriage returned to the harvest area, the weight of the bullhook and chokers was not always sufficient to overcome the drag created by the sag in the mainline. Sometimes a log chunk was attached in the landing to enable the rigging to descend when the mainline was subsequently slacked.

Carriages with radio-controlled mainline and skyline clamps, and small onboard engines dedicated to pulling slack, may overcome the disadvantages of the carriage used in this study. Also, the slackpulling feature eliminates the need for a heavy bullhook, making it considerably easier for the crew to carry the rigging laterally. These advantages must be weighed against the disadvantage of having to maintain a small carriage-mounted engine.

Careful planning and engineering for long-distance cableways is essential. Skyline corridors must be strategically placed and minimum deflection requirements must be met. There are no strict guidelines for maximum skyline and/or yarding distances with these systems, although sometimes 1500 m is considered the limit for large-capacity systems. In practice, these decisions are guided more by local timber prices and harvesting costs than by technical feasibility.

For many reasons, the greater use of long-distance cableways in British Columbia to date has been hindered. It is usually possible to build forest roads and develop harvesting cutblocks for less expensive, conventional tower yarding, and the opportunity cost of losing productive land to forest roads has rarely been considered. For harvesting sites that are inaccessible by road, the use of helicopters has been preferred in recent years. Until recently, harvesting cost allowances under British Columbia's stumpage appraisal system, and the determination of stumpage rates charged for Crown tim-

Figure 12. Lifting logs from gully in Cutblock No. 1.

ber,[4] varied considerably between helicopter and potential alternatives such as long-distance cableways and balloon systems. Stumpage rates and the helicopter's ability to move large volumes of timber, quickly, in response to changing market conditions are factors that likely favoured use of helicopter systems on inaccessible sites in the past. However, similar and more equitable harvesting cost allowances are now in effect for these non-conventional harvesting alternatives. This consistent treatment of harvesting costs should encourage forest operators to focus on the most cost-effective harvesting alternative for a sensitive site.

A long-distance cableway is a low-capital-cost, labour-intensive system capable of providing a steady flow of wood, unimpeded by adverse weather conditions including fog and storms. It can complement other alternative systems, such as helicopters and slack-line tower yarders, to service the sensitive-site component of a watershed's total resource plan. If one considers savings from reduced road construction and the unit costs for Y&L and log hauling when evaluating alternatives, long-distance cableways can be cost-effective on sensitive sites.

Sites where road building is environmentally unacceptable, or where the cost of construction is prohibitive, are primary targets for application of long-distance cableways. The systems can be set up for small cutblocks with small timber volumes and can be adapted to clearcut or partial cutting silviculture prescriptions.

Good rigging skills are needed to install and keep long-distance cableways operating smoothly (Figure 13). A thorough knowledge of methods and designs for anchoring skylines in soil, rock, and standing timber is needed and must be regularly and judiciously applied. The need for these skills, more prevalent during an early era of skyline harvesting in British Columbia, should not be seen as a drawback to using these systems. If local workers are not currently conversant with techniques of cableway operation, they should be capable of acquiring the necessary skills.

Figure 13. Adjusting skyline support saddle on headspar.

The proximity of equipment manufacturers or distributors and the availability of parts and service receive considerable weight in decisions by forest companies and contractors to acquire equipment. Firms feel more secure about adopting alternative types of equipment if they can quickly consult a local representative about its operation and repair. This intangible element has likely played a role in shaping perceptions in western Canada about long-distance cableways, and probably not served in their favour. Local equipment manufacturers have not yet undertaken to produce their own versions of this equipment concept.

Conclusions

The Forest Engineering Research Institute of Canada (FERIC) studied a long-distance cableway system operating on forest land administered by the Greater Vancouver Water District (GVWD) in southwestern British Columbia. Operations were monitored on one 11.0-ha cutblock in 1991 and one 6.1-ha cutblock in 1993. These study sites were located in two of the three major watersheds that provide water for the City of Vancouver and surrounding municipalities. It was important to maintain a low risk of terrain instability following the harvesting activities, and preserve water quality on these sites.

This study provided productivity and cost information for a long-distance cableway system with 10-t payload capacity. Production functions were then derived to predict system productivities and costs over a range of operating conditions. One function estimated average productivity during scheduled yarding time (SYT). This productivity measure is needed to predict wood flow and schedule log hauling after the system has been installed and is operating routinely. SYT includes *delay-free cycle time* (i.e. productive cycle time) plus *delays within cycles*, time to transport fuel to the yarder and fuel-up, major mechanical delays, and service time for system components.

A second production function accounted for system mobilization and demobilization time (MOB AND DEMOB). This enabled predictions of overall harvesting cost for cutblocks with various sizes, shapes, and terrain conditions. MOB AND DEMOB time included moving the sled yarder into position, installation and ten-

[4] In British Columbia, 96% of the timber volume harvested is derived from public lands (commonly referred to as Crown lands).

sioning of the skyline, rig-up of any necessary intermediate supports, and the dismantling of these components following harvesting.

The influence of slope yarding distance and lateral yarding distance on system productivity was then examined. In the analysis, *logs/cycle* was held constant at the study average of 4.2 and the study average volume yarded/cycle of 7.1 m^3 was used. Estimates of productivity, using the study cutblocks as examples, were made using their respective average slope and lateral yarding distances. For Cutblocks No. 1 and No. 2, average slope yarding distances were 500 and 450 m, and average lateral yarding distances were 25 and 30 m, respectively. Productivity and average number of cycles were calculated to be 17.1 m^3/h and 19 cycles/8-h shift in both instances (calculated over SYT which includes delays).

Unit yarding and loading cost, inclusive of system MOB AND DEMOB costs, can vary substantially from cutblock to cutblock depending on sled yarder positioning, and the numbers of skylines and intermediate supports required. Unit costs for Cutblocks No. 1 and No. 2 were calculated as examples. The total timber volume, and an hourly system cost of $337.23, were applied to total time estimates for each cutblock. Graphs generated showed that increases in slope and lateral yarding distances increased the unit yarding and loading cost for each cutblock. The average unit costs for the yarding and loading phases were estimated at $25.25/$m^3$ and $30.83/$m^3$ for Cutblocks No. 1 and No. 2, respectively.

By specifying a long-distance cableway system for harvesting these sensitive sites, the GVWD was able to avoid building new forest roads through difficult terrain into the cutblocks. The harvest system's capacity to fully suspend large payloads, prior to transport down the skyline, helped to preserve gully wall integrity and minimize movement of harvesting debris into gully channels. The skylines were elevated well above previously regenerated cutblocks and little damage to the regenerated stands occurred during yarding.

Long-distance cableways are low-capital-cost, labour-intensive systems capable of providing a steady flow of wood, unimpeded by adverse weather conditions including fog and storms. They can complement other alternative systems, such as helicopters and slack-line tower yarders, to service the sensitive-site component of a watershed's total resource plan. If one considers savings from reduced road construction and the unit costs for Y&L and log hauling when evaluating alternatives, long-distance cableways should prove cost-effective on many sensitive sites.

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Disclaimer

APPENDIX I

Harvesting System Cost Analysis [a]

	Cable-yarding system	Front-end loader
OWNERSHIP COSTS		
Purchase price (P) ($)		260 000
Sled winch ($)	350 000	
Carriage ($)	90 000	
Tensioning clamps, rigging accessories, chain-saw winch ($)	60 000	
Salvage value (S), (30% of P) ($)	150 000	78 000
Expected life (y)	8	8
Hours per year (h/y)	1 200	1 200
Interest rate (Int) (%)	12.0	12.0
Insurance rate (Ins) (%)	2.0	2.0
Average investment (AVI) = (P+S)/2 ($)	325 000	169 000
Loss in resale value = (P-S)/h ($/h)	36.46	18.96
Interest = (Int•AVI)/(h/y) ($/h)	32.50	16.90
Insurance = (Ins•AVI)/(h/y) ($/h)	5.42	2.82
Total ownership costs	74.38	38.68
OPERATING AND REPAIR COSTS		
Hourly fuel consumption (L/h)	12	15
Fuel cost ($/L)	0.40	0.40
Annual wire rope cost (WR) ($/y)		
Skyline ($/y)	12 000	
Mainline ($/y)	9 000	
Chokers ($/y)	6 000	
Annual tire consumption (Ti)		1
Tire replacement cost ($/Ti) ($/y)		2 400
Annual repair & maintenance cost [b] (R) ($/y)	10 000	6 000
Wages (W) ($/h)		
Operator ($/h)	22.95	22.32
Rigging slinger ($/h)	22.32	
Chokersetters (2) ($/h)	20.36	
Landing worker ($/h)	20.92	
Wage benefit loading (WBL) (%)	35	35
Hourly fuel cost = (L)•($/L) ($/h)	4.80	6.00
Lube & oil cost = 10% of hourly fuel cost ($/h)	0.48	0.60
Wire rope cost = WR/(h/y) ($/h)	22.50	
Tire cost = Ti•($/Ti)/(h/y) ($/h)		2.00
Repair & maintenance cost = R/(h/y) ($/h)	8.33	5.00
Labour cost = (W)•(1+(WBL/100)) ($/h)	144.33	30.13
Total operating and repair costs ($/h)	180.44	43.73
TOTAL SYSTEM COSTS ($/h)	254.82	82.41

[a] These figures are based on FERIC'S standard costing methodology for determining machine ownership and operating costs, and do not include such costs as crew transportation, supervision, profit, and office overhead. [b] Annual costs for repairs and maintenance were estimated by FERIC.