Advantage

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Contents

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Helicopter logging with the Eurocopter SA-315B Lama and Kaman K-1200 K-Max: clearcut harvesting in the southern interior

Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied a helicopter logging operation in the southern interior of British Columbia. Two light-lift helicopters were used to harvest a cutblock with several small clearcut units. This report presents productivity and cost information on the helicopter logging operation, and discusses factors affecting the efficiency of the operation.

Keywords

Helicopter logging, Eurocopter SA-315B Lama, Kaman K-1200 K-Max, Clearcut, Productivity, Costs, British Columbia.

Executive summary

FERIC has established an ongoing study of helicopter logging operations throughout British Columbia to provide information on the capabilities and performances of different helicopters in typical harvesting situations. In this study, an Aerospatiale (Eurocopter) SA-315B Lama and a Kaman K-1200 K-Max helicopter were used to harvest a cutblock consisting of several small clearcut units. Helicopter yarding had been prescribed to address numerous concerns including terrain stability, windfall, bark beetle infestation, and protection of native cultural heritage features.

The helicopter operation harvested 5 308 m^3. The overall falling phase averaged 102 m^3 per shift with production (SWP) and the overall loading phase averaged 174 m^3/SWP. For the yarding phase, the Lama helicopter yarded 1 004 m^3 and averaged 126 m^3/SWP, while the K-Max yarded 4 304 m^3 and averaged 287 m^3/SWP. The blended average for both helicopters was 231 m^3/SWP.

The cost of the operation was \$71.68/m^3. The falling cost was \$5.89/m^3 which comprised 8% of the total cost. The helicopter yarding cost for the Lama totalled \$58.81/m^3, which was 11% higher than the K-Max's yarding cost of \$52.94/m^3. The blended average yarding cost for the two helicopters was \$54.04/m^3 and comprised 76% of the total cost. The loading and processing cost was \$11.75/m^3 which comprised 16% of the total cost. The costs of the Lama and K-Max helicopters alone were estimated at \$37.72/m^3 and \$35.53/m^3, respectively, or 64% and 67% of their respective yarding costs.

Falling productivity was adversely affected by steep terrain, deep snow, and windfall which made it time consuming for fallers to move between trees and patches. Furthermore, during the first falling pass, fallers required additional time to judge standing tree weights and select trees that the Lama helicopter could successfully yard. However, the decision not to limb and buck trees at the stump enhanced falling productivity and offset the terrain and snow conditions.

Several factors influenced productivities of the Lama and K-Max helicopters in this study: high cull factor, the two-pass harvesting system, the timing of the operation, sub-optimal landings, and the use of only one loader to support the K-Max.

This report examines several alternative helicopter logging scenarios for this site: increasing in-woods manufacturing, using only the K-Max helicopter for yarding, rescheduling yarding operations, falling in conjunction with yarding, and grapple yarding to supplement choker yarding. The analysis suggested that increasing in-woods manufacturing and eliminating the two-pass harvesting system by using only the K-Max helicopter for yarding would have produced the highest overall cost savings. However, because of extenuating circumstances, the easiest and most realistic cost-savings alternative would have been to commit to an aggressive in-woods manufacturing strategy. Ultimately, this analysis demonstrated the importance of exploring alternative harvesting options prior to committing to a harvesting approach.

The study reflected some of the challenges associated with harvesting with light-lift helicopters in the interior of British Columbia during the winter months. These include the effect of in-woods manufacturing on helicopter yarding productivity, the effect of a two-pass harvesting system on both the falling and yarding phases, the effect of seasonal timing on an operation, the effect of landing location, and the effect of using only one log loader when multiple landings were active.

Introduction

Forest engineers and planners recognize that helicopter logging is a highly specialized system with its own unique requirements for safe, cost-effective harvesting operations. However, information about the capabilities and performances of different helicopters in logging applications is scarce, as is information about site, stand, organizational, and operational factors that influence helicopter logging productivity and cost. FERIC has established an ongoing project to study helicopter logging operations throughout British Columbia to provide this information.

This report presents the results of a case study of a helicopter logging operation in the southern interior on a site where steep and broken terrain limited opportunities for conventional cable yarding. Two light-lift helicopters—an Aerospatiale (Eurocopter) SA-315B Lama and a Kaman K-1200 K-Max—were used to harvest a cutblock consisting of several small clearcut units. FERIC, Ainsworth Lumber Co. Ltd., Airlift Helilog Incorporated, and Grand Island Logging Limited cooperated in this study.

Objectives

The goal of FERIC's project is to provide forest engineers with factual information on the capabilities, productivities, and costs of helicopters currently used for logging in British Columbia through an ongoing series of short-term case studies. There were several specific objectives for this case study:

- Describe the harvesting operation, and determine overall productivities and costs for the falling, helicopter yarding, and loading phases.
- For the yarding phase, compare harvesting productivities and costs for the SA-315B Lama and K-1200 K-Max helicopters.

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- Identify features of the site, stand, harvest plan, and system organization that may have influenced harvesting productivity and cost.

Site and stand description

The study site consisted of one cutblock on Crown land 30 km northwest of Goldbridge or 130 km northwest of Lillooet, in the Cascades Forest District (Table 1). The cutblock was located on a predominantly north-facing slope with elevations from 840 to 1 075 m above sea level. Terrain was steep and broken with average slopes of 75%. Soils were generally sandy loam with rooting depths ranging from 26 to 33 cm. This site was in the Interior Douglas-fir dry cool subzone (IDFdk2) (Lloyd at al. 1990). Forest cover consisted primarily of interior Douglas-fir (*Pseudotsuga menziesii*) with secondary components of Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*), and minor components of whitebark pine (*Pinus albicaulis*), western red cedar (*Thuja plicata*), and amabilis fir (*Abies amabilis*). Merchantable volume averaged 330 m^3/ha and ranged from 300 to 400 m^3/ha. The study site had a considerable amount of windthrow and a severe infestation of Douglas-fir bark beetle.

Harvesting prescription and plan

The study site was cruised and engineered by Ainsworth. Harvesting by helicopter was prescribed for this area to address numerous concerns including terrain stability, windfall, bark beetle infestation, and protection of streambanks and native cultural heritage features. The average tree size of 0.7 m^3 indicated the use of a light-lift helicopter. The successful bidder, Airlift Helilog, initially proposed to harvest the site with a Kaman K-1200 K-Max helicopter. Because this helicopter was unexpectedly delayed, a Eurocopter SA-315B Lama helicopter was used for a short period before the K-Max became available. Harvesting operations were scheduled for winter in an effort to eradicate the Douglas-fir bark beetle populations present in the windthrow. According to the B.C. Ministry of Forests Bark Beetle Guidebook (BCMOF and BC Environment 1995), helicopter harvesting to control Douglas-fir bark beetle is feasible from September to March.

The cutblock consisted of six units and was laid out for a combination of clearcut cable and helicopter yarding. Four of the units, ranging in size from 1.7 to 4.1 ha, were prescribed for helicopter yarding. These units were irregularly shaped owing to numerous rocky outcrops. Two units had steep gullies extending top to bottom. Three landings approximately 0.1 ha in size were located on the main road, downslope from the cutblock (Figure 1). Landings 1 and 2 served Units 1 and 2 and were approximately 425 m apart. Landing 1 was the main landing while Landing 2 was an overflow landing. Landing 3, approximately 800 m west of Landing 2, served Units 3 and 4. The service landing for helicopter refuelling and maintenance was located about 50 m west of Landing 3 on the main road. Unit-to-landing horizontal

Table 1. Site and stand description

Cutblock area (ha)	20
Ecological classification	IDFdk2
Terrain	
Terrain description	broken, rocky outcrops
Average slope (%)	75
Mass wasting hazard	moderate to very high
Stand characteristics	
Species composition (%)	
Douglas-fir	73
Engelmann spruce	12
lodgepole pine	11
whitebark pine	2
western red cedar	1
amabilis fir	1
Defect (% gross)	
Decay	8
Waste	2
Breakage	3
Merchantable volume (m^3/ha)	330
Forest health concern	Douglas-fir bark beetle

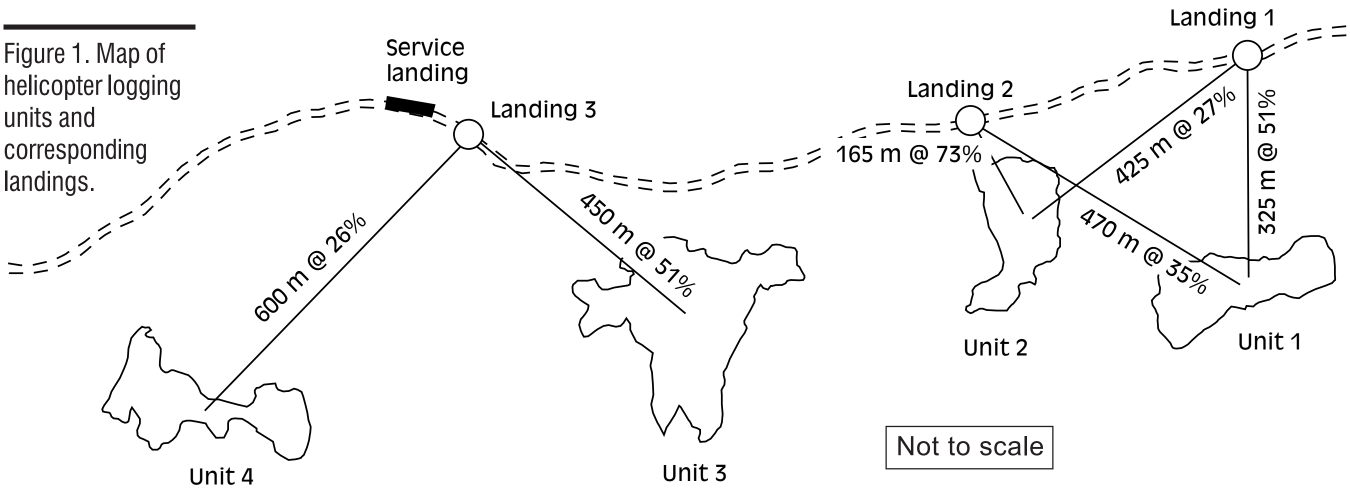


Figure 1. Map of helicopter logging units and corresponding landings.

flight distances ranged from 165 m to 600 m and flight path slope gradients ranged from 26 to 73%. Refer to Dunham (2004a) for information on estimating yarding distance for helicopter logging operations.

Helicopter specifications

Eurocopter SA-315B Lama

The Lama is a light-lift[1] helicopter powered by a single turbine engine (Figure 2).[2]

Figure 2. Eurocopter SA-315B Lama helicopter.

It was originally designed in the late 1960s for military use by Indian armed forces and was subsequently adapted and marketed for civilian applications after it received commercial certification in the United States in 1972. Until recently it held the the record for highest landing and takeoff and is the only helicopter ever produced that can lift its own weight.

Specifications for the Lama are presented in Table 2. With a rated payload of approximately 2 500 lb., the Lama is one of the smallest helicopters routinely used for logging in British Columbia. See Appendix I for a list of helicopters commonly used for logging in British Columbia.

Kaman K-1200 K-Max

The K-Max is a light-lift helicopter powered by a single turbine engine, and is designed primarily for logging, fire-fighting, and construction (Figure 3).[3] It has a unique rotor design consisting of two double-bladed, counter-rotating, intermeshing rotors, which

Table 2. Specifications for the Lama and K-Max helicopters

	Lama	K-Max
Rated lift capacity (lb.)	2 500	6 000
Engines (no.)	1	1
Engine power at takeoff (kW)	640	1 342
Dimensions of main rotor (m)	11.0	14.7 (each)
Dimensions of tail rotor (m)	1.9	n/a
Service ceiling (m)	5 400	4 572
Standard fuel capacity (L)	573	865

1 In general, logging helicopters are classified on the basis of their maximum rated payload as either light-lift (less than 10 000 lb.), medium-lift (10 000–15 000 lb.), or heavy-lift (more than 15 000 lb.).

2 The Lama was originally manufactured by Sud Aviation, hence the "SA" in the model number. Sud Aviation became part of Aerospatiale in the 1970s. In 1992, the helicopter divisions of Aerospatiale-mantra (France) and Daimler Chrysler Aerospace (Germany) merged and the company was renamed Eurocopter Group.

3 The K-Max is manufactured by the Kaman Aerospace Corporation of Bloomfield, Connecticut.

eliminates the need for a tail rotor. Also, the K-Max accommodates only one pilot. The K-Max was certified for commercial use in the United States in 1994, and since then 28 units have been built.

Specifications for the K-Max are presented in Table 2. With a rated payload of approximately 6 000 lb., the K-Max is one of the largest light-lift helicopters routinely used for logging in British Columbia.

Figure 3. Kaman K-1200 K-Max helicopter.

Study methods

A FERIC researcher was on-site for part of the harvesting operation and collected shift-level and detailed-timing information. Shift-level information for the falling, yarding, and loading phases was supplied by cooperators and included shift production reports and daily operating reports. Complete shift-level information was obtained for the Lama but not for the K-Max. During the yarding phase, FERIC frequently discussed the progress of the harvesting operation with Ainsworth and Airlift Helilog personnel to identify site, stand, layout, and organizational factors that influenced the helicopters' productivities.

Shift-level and detailed-timing records were used to estimate average turn times, flight distances, number of turns, and total weight of logs yarded. Scale summaries were supplied by Ainsworth and were used to convert turn weights to volumes.

Costs for the Lama and K-Max helicopters were estimated using a modified version of the costing methodology in Guimier and Wellburn (1984), supplemented with information from the Official Helicopter Blue Book and Helicopter Equipment Lists & Prices (HeliValue$, Inc. and Helibooks Ltd. 2004) and the 2004 Helicopter Annual (Helicopter Association International 2004) (Appendix II). A computer program was also used to help determine helicopter costs.[4] Hourly costs for other machinery involved in the harvesting operations were calculated using FERIC's standard costing methods (Appendix III). Labour rates were based on union wage rates and adjusted to reflect the fact the harvesting operation was non-union.

FERIC's cost estimates do not include stumpage or profit. The costs presented in this report are FERIC's estimates only and are not the actual costs incurred by either the licensee or the helicopter contractor. Cost estimates are not influenced by project-specific circumstances such as contractor or project economies of scale, and market and business conditions. These circumstances may have a considerable influence on logging costs and, as a result, the contractor's or licensee's actual costs may vary significantly from FERIC's estimates. A sensitivity analysis on helicopter hourly operating cost was presented in Dunham (2004a).

Results and discussion

Description of harvesting operation

Airlift Helilog[5] was responsible for the yarding activities and stump-to-dump supervision, while falling and loading were performed by Grand Island Logging. At the time of the study, all crews were experienced in helicopter logging operations. Harvesting began in early December and was completed in early February.

4 Aircraft Cost Evaluator, 2004 version, by Conklin and de Decker Associates.

5 Airlift Helilog owned and operated the Lama helicopter and used its own rigging, landing, and flight crews for yarding. The K-Max helicopter, flight crew, and maintenance crew were leased by Airlift Helilog from MidWest Helicopters Ltd. of Winnipeg, Manitoba.

Manual falling began in December and was carried out by a crew of two or three fallers. The fallers also built helipads from on-site materials for their own use and for the rigging crew's use. Trees were felled cross-slope. Deep snow made falling and limbing difficult, so in-woods manufacturing was not done.

Units 1 and 4 were felled prior to Airlift Helilog's decision to use the Lama helicopter and Units 2 and 3 were felled afterward in two passes. In the two-pass system, patches of small trees suitable for yarding with the Lama were felled in the first pass and the remaining trees were felled for the K-Max in the second pass. Fallers walked to and from Units 1 and 4 each day, which took 30 to 40 minutes per shift. In Units 2 and 3, however, fallers were flown to and from their worksites each day because the Lama or a Hughes 369D support helicopter was always on-site. Approximately 10–20 minutes of helicopter time per shift were required to ferry the fallers into and out of the blocks.

The K-Max helicopter was originally scheduled to perform all of the helicopter logging on this cutblock but unscheduled maintenance delayed its arrival by several weeks. To reduce concerns about snowfall accumulations on already-felled timber and also to meet Ainsworth's wood flow requirements, Airlift Helilog decided to start logging with the Lama and to log the cutblock in two passes. The Lama helicopter would yard the logs it was capable of lifting in the first pass, and the K-Max would yard the remaining logs that the Lama couldn't lift in the second pass.

The Lama was equipped with a 14-kg hook and a 60-m longline, and the K-Max was equipped with a 60-kg hook and a 45-m longline. The yarding crew consisted of flight, helicopter maintenance, rigging, and landing personnel, and generally comprised 7 personnel for the Lama operations and 12 personnel for the K-Max operations (Table 3). Additionally, both helicopters employed an on-site woods foreman who often assisted with rigging and bucking tasks.

Helicopter maintenance equipment for both helicopters included an on-site service trailer, truck-mounted fuel tank, aircraft refuelling system, and an aircraft blade de-icing/anti-icing system. Maintenance schedules varied for the two helicopters. No pre-shift maintenance was conducted on either helicopter. The Lama shut down for a ten-minute mechanical inspection following every second yarding cycle, but no routine in-shift maintenance inspections were carried out on the K-Max. For both machines, helicopter engineers were generally on-site during most of the yarding shift but most scheduled maintenance was performed post-shift. Major helicopter component repairs or changes were done at Airlift

Table 3. Crew complement for the yarding phase

	Lama		K-Max	
Crew description	Crew position	Crew size	Crew position	Crew size
Flight crew	Lama pilot	1	K-Max pilot Hughes pilot	1 1
Rigging crew	Hooktenders	3	Hooktenders	5
Landing crew	Chaser Landing bucker	1 0	Chasers Landing bucker	3 1
Maintenance crew	Flight engineers	2	Flight engineer	1
Totals		7		12

Helilog's hangar near Pitt Meadows, B.C., rather than on-site. During the project, the Lama did not need to return to the base hangar for maintenance, while the K-Max returned for one day.

The rigging crews worked a scheduled 9 to 10-h shift. Each hooktender worked individually to assemble, set, and hook turns. The hooktenders were evenly spaced across each of the active units to ensure they did not work under the logging helicopter's flight path. The helicopter took four to six consecutive turns from each hooktender before moving to the next rigger. Both helicopters followed a fixed rotation among the rigging crew, generally visiting each hooktender two or three times during a typical yarding cycle. Generally, the logging helicopters yarded from only two units each shift, alternating service between each unit, but all units were harvested concurrently. The active units varied each shift depending on the helicopter, falling progress, and weather conditions.

The average effective scheduled shift length for both helicopters was 9.1 hours. The Lama generally flew 5 hours in a typical full shift, yarding 44 to 48 turns in a 1.2- to 1.3-hour yarding cycle. The K-Max generally flew about 5.9 hours in a typical full shift, yarding 40 to 44 turns in a 1.2- to 1.3-hour yarding cycle. At the end of each yarding cycle, the Lama and K-Max helicopters returned to the service landing for "hot" refuelling (i.e., refuelling while the engine is running). Refuelling times averaged 5–7 minutes for the Lama and 10–15 minutes for the K-Max.

A Hughes 369D helicopter spent 1.5 to 2 hours each shift to support the K-Max by returning chokers to the rigging crew and transporting falling and rigging crews to and from worksites. The Lama performed its own support activities.

A hydraulic loader cleared, decked, and spread logs for processing by the landing buckers, and loaded the manufactured logs onto trucks for hauling. Scheduled loading shifts ranged from 12 to 14 hours (single shift) when the Lama was yarding and 17 to 19 hours (double shift) when the K-Max was yarding. When the K-Max was yarding, the woods foreman also usually worked 4 to 5 hours each night limbing and bucking stems in the landings. Night bucking was carried out to ensure the landings were clear of logs before the yarding crew arrived the next morning.

Harvesting productivity and cost

A total volume of 5 308 m^3 (from scale records) was harvested from the study site. Overall, the falling phase averaged 102 m^3 per shift with production (SWP) and the loading phase averaged 174 m^3/SWP. For the yarding phase, the Lama yarded 1 004 m^3 and averaged 126 m^3/SWP, while the K-Max yarded 4 304 m^3 and averaged 287 m^3/SWP. The blended average production for both helicopters was 231 m^3/SWP. The total stump-to-truck harvesting cost was estimated at \$71.68/m^3 (Table 4). The yarding cost for the Lama totalled \$58.81/m^3, which was 11% higher than the K-Max's yarding cost of \$52.94/m^3. Yarding comprised the largest portion (76%) of the total harvesting cost, followed by loading and processing at 16% and falling at 8%.

The average stump-to-truck cost in this study is considerably lower than the cost reported in Dunham (2004a) of \$80.17/m^3 for a Bell 214B helicopter also working in the southern interior. The falling cost is higher in this study and is mainly attributed to the deep snow and the extra time required to accurately judge standing tree weights and to select trees for two-pass harvesting. Conversely, the yarding cost in this study was substantially lower than in the Bell 214B study. This is attributed to shorter average flight distances and more favourable landing sizes. Loading and processing costs between the two studies were similar.

Falling

Falling operations began in early December and, except for a two-week period in late December, continued fairly steadily until completion in January. In 21 days of falling,

Table 4. Estimated costs of falling, yarding, and loading

	Falling ($/m³)	Yarding: Lama ($/m³)	Yarding: K-Max ($/m³)	Yarding: Blended [a] ($/m³)	Loading ($/m³)	Total ($/m³)
Prime costs						
Yarding helicopter		37.72	35.53	35.94		35.94
Support helicopter	1.47		1.81	1.47		2.94
Other equipment [b]		0.29	0.08	0.12	6.82	6.94
Chainsaws	0.56	0.46	0.20	0.25	0.32	1.13
Choker replacement		0.63	0.26	0.33		0.33
Labour	2.54	7.98	6.90	7.10	2.64	12.28
Subtotal	4.57	47.08	44.78	45.21	9.78	59.56
Other costs						
Mobilization		2.57	0.86	1.18	0.27	1.45
Crew transport	0.79	0.89	0.38	0.48	0.91	2.18
Supervision		3.09	1.34	1.67		1.67
Crew room and board	0.39	3.19	1.38	1.72	0.51	2.62
Overhead	0.14	1.99	1.79	1.83	0.28	2.25
Project costs			2.41	1.95		1.95
Subtotal	1.32	11.73	8.16	8.83	1.97	12.12
Total	5.89	58.81	52.94	54.04	11.75	71.68

[a] Weighted average cost for the entire yarding phase.

[b] Other equipment for the yarding phase includes on-site service trailer, truck mounted fuel tank, aircraft refueling system and an aircraft blade de-icing/anti-icing system.

a crew of 2 to 3 fallers worked a total of 52 faller shifts to fall timber and build helipads. Shift time also included flying and hiking to and from the falling sites and in-shift delays. The support helicopter was used for 15 flight-hours[6] to ferry fallers to and from worksites. Based on a volume of 5 308 m³, each faller produced an average of 102.1 m³/6.5-hour shift (Table 5). Falling productivity was adversely affected by steep terrain, deep snow, and windfall which made it time-consuming for fallers to move between trees and patches. Furthermore, during the first falling pass, fallers required additional time to accurately judge standing tree weights and select trees that the Lama could successfully yard. However, the decision not to limb and buck felled trees at the stump enhanced falling productivity and offset the terrain and snow conditions. As a result, average falling productivity in this study was higher than the falling productivity of 91.2 m³/6.5-h faller shift reported in Dunham (2004a).

Loading

Loading activities began at the same time as the yarding phase. A total of 366 hours was spent loading (96 hours when the Lama was yarding and 270 hours when the K-Max was yarding). A landing bucker spent 135 hours bucking for the K-Max. A landing bucker was not needed when the Lama was yarding because most of the bucking was carried out by the woods foreman. As well, the woods foreman spent an additional 4 to 5 hours bucking each night for the K-Max. Since the woods foreman's time was charged to supervision, the project's processing costs are somewhat understated.

Landing size and design were considered adequate by Airlift Helilog's pilots. However,

[6] The minimum charge for the support helicopter was two flight-hours per shift for production for the logging helicopter, although the support helicopter's actual flight time per shift was actually 1.5 to 2.0 hours. Support helicopter time was not charged separately to the falling and yarding phases. FERIC arbitrarily assigned half to each phase.

Table 5. Shift-level productivities for the falling, yarding, and loading phases

	Lama	K-Max	Combined
Falling			
Scheduled shifts worked (no.)	-	-	21
Non-productive shifts (no.)	-	-	0
Average fallers per scheduled shift worked (no.)	-	-	2.5
Total productive faller-shifts worked (no.)	-	-	52
Production per 6.5-h faller shift (m^3)	-	-	102.1
Yarding			
Logging helicopter			
Potential shifts (no.)	9	16	25
Non-operating shifts (no.)	1	1	2
Shifts with production (SWP) at study site (no.)	8	15	23
Average flight-hours per SWP (no.)	5	5.9	5.6
Production per SWP (m^3)	125.5	286.9	230.8
Loading			
Scheduled shifts worked (no.)	-	-	38
Production per 12-h loading shift [a] (m^3)	-	-	174

[a] Loading shifts varied in length, so a 12-h shift length was arbitrarily selected by FERIC to express shift production.

there was only one loader for the K-Max yarding operation. This often resulted in congestion and delays in the landings operating without the loader and also resulted in downtime for the logging helicopter, even though the loader moved between landings during the shift.

Yarding

Helicopter yarding began in mid-January and operated seven days a week for 23 productive shifts (Table 5). The Lama yarded 1 004 m^3 in 8 productive shifts and the K-Max yarded 4 304 m^3 in 15 productive shifts.[7] During this time, one yarding shift was lost for maintenance on the K-Max and one shift was lost waiting for fallers to finish falling. Although Airlift Helilog scheduled yarding operations from 8:00 AM to 5:30 PM (9.5 hours), several non-project-related tasks reduced the Lama's average yarding shift length to 8.3 hours, while the average yarding shift length for the K-Max remained at 9.5 hours. The weighted average yarding shift length for the entire project was 9.1 hours. Scheduled start and end times for the falling and loading crews were not affected.

Table 6 summarizes time distributions for productive shifts based on the average 9.1-hour shift length. Post- and full-shift maintenance and shifts lost for reasons unrelated to the project are excluded. A total of 128.3 flight-hours for both helicopters was required to yard the total project volume of 5 308 m^3. This represents 62% of potential yarding time. Scheduled maintenance and refuelling time were estimated at 7% of total scheduled hours. Therefore, flight time and associated service activities accounted for 69% of the total hours potentially available for yarding. Additionally, 15% of potential shift time was lost to poor weather, 6% to unscheduled maintenance, and 10% to crew transportation (to and from worksites via helicopter or by foot) (Figure 4).

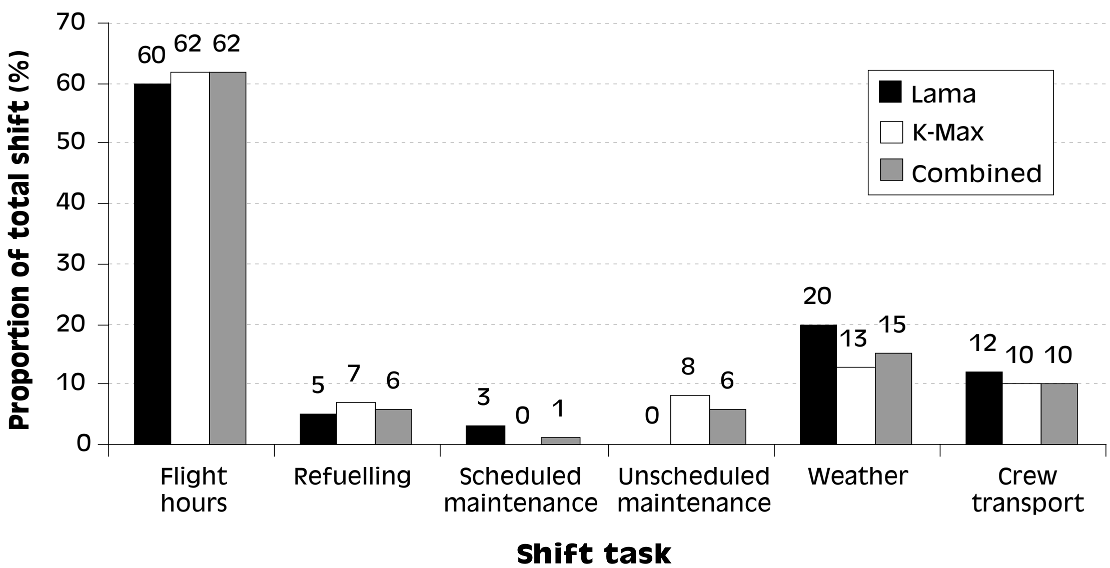
The ratio of flight-hours to total hours was similar for the two helicopters (60% for the Lama and 62% for the K-Max). The

[7] A total of 2 209 m^3 was harvested by the logging helicopters during the time FERIC was on-site and yarding shift-level information for this portion of the operation was made available to FERIC. Production estimates for the K-Max for the period for which shift-level data were not available were extrapolated from the available shift-level data and the scaled volume.

Table 6. Shift-level time distributions for productive shifts

	Lama	K-Max	Combined
Flight time			
Shifts with production (no.)	8	15	23
Total flight-hours (h)	39.8	88.5	128.3
Flight-hours/productive shift (h)	5.0	5.9	5.6
Non-flight time			
Scheduled in-shift maintenance (h)	2.0	0.0	2.0
Refueling (h)	3.2	10.1	13.3
Unscheduled in-shift maintenance (h)	0.0	12.0	12.0
Weather (h)	13.1	18.0	31.1
Crew transportation	8.0	13.5	21.5
Subtotal (h)	26.3	53.6	79.9
Total potential hours (h)	66.1	142.1	208.2
Ratio of flights hours to total potential hours (%)	60	62	62

Figure 4. Shift distribution for the Lama and K-Max helicopters.



K-Max achieved a slightly higher flight-hour ratio because it experienced a lower proportion of in-shift weather downtime. Also, the K-Max had more available flight time each day because no shutdowns for scheduled in-shift maintenance occurred during this project. The ratio of flight-hours to total hours for this study (60–62%) is comparable to other recent FERIC helicopter logging studies (Dunham 2003, 2004a) with ratios ranging from 60 to 66%, and which were conducted during late fall to early spring, when weather conditions are generally poorest.

In-shift helicopter maintenance for this operation accounted for only 1% of scheduled time, compared to 7–16% for other FERIC helicopter logging studies (Dunham 2002, 2003, 2004a, b). Airlift Helilog deferred most of the scheduled in-shift maintenance on the helicopters to post-shift because daily average flight-hours were relatively low owing to short daylight hours and poor weather conditions. Under Transport Canada regulations in effect at the time of this study, regular in-shift maintenance inspections were not required for either the Lama or the K-Max.

Table 7. Yarding production summary	Lama	K-Max [a]	Combined
Production totals			
Total flight-hours (no.)	39.8	88.5	128.3
Cycles flown (no.) [b]	31	68	99
Turns yarded (no.)	1 477	2 969	4 446
Weight yarded (lb.)	2 951 470	12 825 920	15 777 390
Volume yarded (m^3)	1 004	4 304	5 308
Weight-to-volume conversion factor (lb./m^3)	2 940	2 980	2 972
Production per SWP			
Cycles (no./SWP) [c]	4	5	n/a
Turns (no./SWP)	185	198	n/a
Weight yarded (lb./SWP)	368 934	855 061	n/a
Volume yarded (m^3/SWP)	125.5	286.9	n/a
Production per flight-hour			
Turns (no./flight-hour)	37.1	33.5	n/a
Weight (lb./flight-hour)	74 158	144 926	n/a
Volume (m^3/flight-hour)	25.2	48.6	n/a
Production per turn			
Average turn time (min)	1.62	1.79	n/a
Weight (lb./turn)	1 998	4 320	n/a

[a] Shift-level data were incomplete. Project totals are estimated by extrapolating from available data, supplemented by field observations and discussions with cooperators.
[b] Cycles flown by the K-Max were estimated by FERIC assuming a 1.3-hour cycle length.
[c] Rounded to the nearest whole number.

Table 7 summarizes and compares yarding productivities for the Lama and the K-Max. A total payload of 15 777 390 lb. (5 308 m^3 net scale) was flown by the two helicopters, yielding a weight-to-volume conversion ratio of 2 972 lb./m^3 for this project. The average turn times for the Lama and K-Max were 1.6 and 1.8 minutes, respectively, at an estimated horizontal yarding distance of 431 m for both helicopters.

Target and actual payloads for this operation were 2 200 and 1 998 lb., respectively, for the Lama and 5 000 and 4 320 lb., respectively, for the K-Max. These represent average load factors of 80% of rated payload capacity for the Lama and 72% for the K-Max. Therefore, the Lama helicopter was slightly more efficient at reaching targeted payloads than the K-Max helicopter. The K-Max had more difficulty meeting target payloads because logs were scattered and the range of piece sizes available was reduced as a result of the two-pass yarding system. Inevitably, this complicated the task of assembling optimum turns and made it more difficult to make incremental increases to turn payload. However, even though the K-Max's payloads were not as close to targets as the Lama, the K-Max was able to yard more than twice the Lama's payload in roughly the same amount of time for the same horizontal yarding distance, and at less than double the all-found yarding cost. Overall, the K-Max helicopter was more cost-effective than the Lama for this project.

Detailed-timing study

The K-Max was detail-timed for four yarding cycles over two shifts to provide information about average turn times, payloads, and time distribution within a typical turn (Table 8).[8] Average turn time for

[8] The Lama was not detail-timed.

Table 8. Summary of detailed-timing study

Average delay-free turn time (min/turn)	1.71
Full or part cycles (no.)	4
Turns (no.)	122
Logs (no.)	244
Flight distance	
Range (m)	325–420
Average (m)	376
Flight path slope	
Range (%)	18–57
Average (%)	46
Total payload	
Range (lb.)	4 400–6 600
Average (lb.)	5 303
Turn time distribution (%)	
Fly empty	20
Hookup & breakout	45
Fly loaded	27
Unhook	8

the detailed-timing period (1.71 min/turn) was 4.5% shorter than the K-Max shift-level average of 1.79 min/turn (Table 7). The average turn payload for the detailed-timing period was 5 303 lb./turn, or 88% of the K-Max's rated load capacity of 6 000 lb./turn, and was substantially higher than the shift average of 4 320 lb./turn or 72% of rated payload. This represents a 22.8% increase in payload over the shift-level average for the K-Max. The average turn times and payloads translate into productivities of 186 000 lb. and 62.4 m^3 per flight-hour for the detailed-timing period, and 145 000 lb. and 48.6 m^3/flight-hour for the shift-level study.[9] By comparison, if the K-Max had achieved its target payload of 5 000 lb./turn (83% of rated payload) in the same average turn time as observed for the shift-level study, it would have averaged 166 600 lb. and 56.2 m^3/flight-hour.

The turn time distribution for the K-Max (Table 8) is very similar to distributions reported for other logging helicopters in other FERIC helicopter logging studies (Dunham 2003, 2004a, b).

Five turns were aborted during the detailed-timing study, for an abort rate of 4.1%. The high abort rate[10] was attributed to the deep snow, which made it difficult for hooktenders to estimate turn weights and made breakouts more difficult because logs were sometimes frozen together in the snowpack.

Factors affecting helicopter yarding productivity

During the study, the cooperators identified several factors that they believed affected the productivities of the Lama and K-Max and the overall cost of the harvesting operation. The key factors were a high cull factor, the two-pass harvesting system, the timing of the operation, sub-optimal landings, and the use of only one loader to support the K-Max.

Cull factor

Cull factor is the weight of unmerchantable or cull material flown to the landing, expressed as a percentage of the total weight of wood flown. The average conversion ratio for this project (total weight flown divided by scaled net volume) was 2 972 lb./m^3, significantly higher than cooperators expected. The average conversion factors for logs yarded by the Lama and K-Max helicopters were very comparable at 2 940 and 2 980 lb./m^3, respectively. FERIC estimated the cull factor for this project at 25–30%. Therefore, on average one-quarter of the helicopter's payload for each turn consisted of unmerchantable wood or frozen snow. The difference between the estimated or expected weight-to-volume conversion factor and the actual conversion factor was largely owing to leaving trees full-length and unlimbed. Additionally, frozen snow on top of felled logs also contributed to the higher per-unit

[9] Assuming an average weight-to-volume conversion factor of 2 980 lb./m^3 (Table 7).

[10] Heli-logging contractors typically try to achieve abort rates between 2 and 3%.

weight.[11] According to Adamovich (1979), this is within the expected range for interior Douglas-fir trees where 20–25% of the total weight of a "whole" dry interior Douglas-fir tree consists of branches and a top less than 10 cm in diameter. The results suggest the high conversion factor could have been considerably reduced with more intensive in-woods manufacturing, and by carrying out yarding operations when heavy snowfall was not a factor.

Two-pass harvesting system

Two-pass harvesting affected the productivities of both the falling and yarding phases. In the first pass, falling productivity was reduced because fallers needed more time to estimate standing tree weights and select trees that were small enough for the Lama to lift. In the second pass, yarding productivity was reduced because logs left behind following the first yarding pass were scattered and generally large. This reduced the piece size blend and made it difficult for the riggers to build optimal turns for the K-Max. As a result, the K-Max averaged only 72% of rated payload per turn for the four days with data, compared to 80% for the Lama.

Timing of the operation

Heavy snow, cold temperatures, and low cloud caused the logging helicopters to be idle for an estimated 15% of potential flight time. According to shift-level data, weather-related downtime accounted for 20% of potential flight time for the Lama and 13% for the K-Max. The difference in weather-related downtime between the two helicopters was attributed to the greater frequency of heavy snow and low cloud in early January when the Lama was operating, compared to late January and February when the K-Max was operating. According to Airlift Helilog, 15% or more of scheduled operating time during December and January is typically lost to snow, low cloud, and fog. Additionally, further downtime during periods of very cold temperatures (i.e., less than -15°C) often results in operating and mechanical problems with the logging helicopter. For example, the rotor blades on both helicopters frequently iced over during yarding operations, requiring the helicopter to shut down for de-icing during the shift.

Heavy snowfalls also caused some merchantable logs to be missed by the rigging crews. Missed logs represent a loss of revenue to the company and the heli-loggers, and compromise the licensee's ability to meet required fibre recovery standards. Less downtime would likely have resulted if this project had been carried out either earlier or later within the September to March window, when there is less risk of heavy snowfalls and very cold temperatures.

Landing location

Landing 3 was located at the bottom of an avalanche chute which was of concern because harvesting was carried out during the winter. This landing could have been moved 75–100 m in either direction of its location with little effect on flight distance or flight path slope gradient. Also, Landing 1 could have been located on a partially deactivated spur road above its location. This would have reduced horizontal distances from Units 1 and 2 by approximately 130 and 230 m, respectively, with little increase in flight path slope. The shorter flight distances might have reduced fly empty and fly loaded times by as much as one minute per turn. However, dramatic turn time reductions can have other implications such as requiring additional hooktenders to supply the helicopter; increasing pilot fatigue because more time is spent performing vertical reference flight; and increasing the landing crew, equipment complement, and landing size to handle the additional volume.

Use of only one loader

Although one loader was adequate to handle the daily yarded volume during the Lama operation, it was not sufficient to

[11] It was estimated that heavy snow loading added an additional 8–10% to average turn weight.

handle the volume produced by the K-Max. Having only one loader on site during the K-Max operation caused congestion at the landing and often resulted in downtime for the K-Max because there was no space available to safely land logs.

Comparing alternative harvesting scenarios

Forest engineers and helicopter logging contractors often need to evaluate a variety of harvesting scenarios for a site to determine the best option for a helicopter logging project. Two alternatives are discussed here. Scenario 1 examines the costs and benefits of increasing the level of in-woods manufacturing. Scenario 2 examines the effects of increasing the level of in-woods manufacturing and using only the K-Max helicopter for yarding, as planned originally.

The following major assumptions were used:

For Scenarios 1 and 2:

- Average cull factor was reduced to 15%.
- Loading productivity was unchanged.
- Bucking productivity at the landings was increased by 10%, as a result of greater in-woods manufacturing.

For Scenario 1 only:

- Falling productivity was decreased by 25% as a result of greater in-woods manufacturing.

For Scenario 2 only:

- Falling was done in one pass and, therefore, overall falling productivity was increased by 5%. The net effect of greater in-woods manufacturing (as per Scenario 1) on falling productivity was a net decrease of 20%.
- Helicopter yarding was done in one pass with the K-Max helicopter.
- The K-Max was not delayed and yarding operations began in early January.
- Weather-related in-shift helicopter downtime accounted for 13% of total potential shift time and the K-Max averaged 5.9 flight-hours/SWP.
- The K-Max helicopter achieved an average of 48.6 m^3/flight-hour.

Table 9 compares the two alternatives with the outcome for this study.

Scenario 1 resulted in an estimated cost savings of \$4.83/m^3 compared to the status quo. Although in-woods manufacturing resulted in a higher overall falling cost, the reduction of cull yarded to the landing increased the proportion of total merchantable weight to total weight per turn. As a result, increases in falling cost were more than offset by decreases in yarding and loading phase costs.

Scenario 2 resulted in an estimated cost savings of \$7.07/m^3 compared to the status quo. By conducting in-woods manufacturing and eliminating two-pass falling, fallers working in Units 3 and 4 would not have required additional shift time to judge standing tree weights. Additionally, by eliminating two-pass yarding and using only the K-Max which was better suited to the average piece size in the cutblock, yarding production per flight-hour was almost doubled (48.6 vs. 25.1 m^3/flight-hour) at an all-found yarding cost of only 43% more than the Lama. Single-pass yarding would have also increased the piece size blend available to the K-Max and may have resulted in a higher average turn payload, higher per flight-hour yarding productivity, and a lower unit yarding cost.

There are several other alternative harvesting options that might also have been considered:

Re-scheduling yarding operations. Scheduling yarding operations for the late fall or early spring to avoid heavy snowfalls and very cold temperatures, yet still take advantage of the cooler temperatures required to contain bark beetle spread, would have lessened snow

Table 9. Estimated costs for Scenarios 1 and 2

	Scenario 1	Scenario 2	This study
Falling (\$/m^3)	7.07	6.28	5.89
Yarding (\$/m^3)	48.10	46.65	54.04
Loading (\$/m^3)	11.68	11.68	11.75
Total	66.85	64.61	71.68

loading on felled timber. It was estimated that heavy snow loading added an additional 8–10% to average turn weight. Additionally, heavy snow loading and logs frozen together increased the time and difficulty required for breakout. Heavy snow loading as a result of the time of harvest caused logs to become buried and, consequently, left behind and not yarded. Also, it is likely that in-shift weather-related downtime would have been reduced if yarding operations had not been carried out during the winter. Weather downtime for this project was estimated at 13% of total potential shift time, more than double the weather downtime experienced in other FERIC helicopter logging studies (Dunham 2003, 2004b) conducted in the fall or spring months.

Falling in conjunction with yarding. In Units 1, 2, and parts of Units 3 and 4, falling was carried out several days or weeks prior to yarding which resulted in heavy snow loading on felled timber. Carrying out falling operations one or two days ahead of yarding may have significantly reduced the amount of snow on felled timber and decreased the amount of snow yarded each turn. Reduced snow loading would have made finding, locating, and breaking out turns less difficult and time-consuming, as well as decreased the amount of non-revenue weight flown each turn. However, falling in close conjunction with yarding operations requires comprehensive and careful planning, and if not done well could result in additional helicopter downtime.

Grapple yarding to supplement choker yarding. Grapple yarding while the rigging crew was hiking or flying into and out of work areas each shift could have increased the productive flight time by up to 30–40 minutes per shift. Grapple yarding may have also reduced the amount of weather-related helicopter downtime experienced because grappling can often be performed in weather conditions that are not suitable for rigging crews. Grapple yarding productivity in weather conditions as encountered in this study would be considerably less than in conditions where snow loading was not a factor. Snow loading makes grapple placement more difficult and time-consuming, and inevitably limits productive grappling mainly to larger, more visible logs.

In summary, increasing the level of in-woods manufacturing and eliminating the two-pass harvesting system by using only the K-Max for yarding would have produced the highest overall cost savings at $7.07/m^3. However, because of extenuating circumstances including meeting Ainsworth's wood flow requirements, and because foreseeing the K-Max's unexpected maintenance requirements was not possible, the easiest and most realistic cost-saving alternative would have been to commit to an aggressive in-woods manufacturing strategy. Ultimately, this analysis demonstrates the importance of exploring different alternative harvesting scenarios prior to committing to a harvesting approach.

Conclusions

Ainsworth harvested several small units within a clearcut northwest of Goldbridge in the Cascade Forest District using a two-pass harvesting system with a combination of two light-lift helicopters to address numerous concerns including terrain stability, windfall, bark beetle infestation, and protection of streambanks and native cultural heritage features. A total of 5 308 m^3 was harvested during the project, consisting of 1 004 m^3 yarded by a Eurocopter SA-315B Lama helicopter and 4 304 m^3 yarded by a Kaman K-1200 K-Max helicopter. The area was felled during December and January in 52 faller shifts. The falling crew varied in size from 2 to 3 fallers and averaged 102.1 m^3/6.5-hour shift. The Lama carried out first-pass yarding and yarded for 8 productive shifts, averaging 25.1 m^3/flight-hour. The K-Max carried out second-pass yarding and worked for 15 productive shifts, averaging 48.6 m^3/flight-hour. One hydraulic log loader completed clearing, decking, and loading activities in 38 shifts, averaging 174 m^3/12-hour loading shift.

Detailed timing was performed for only the K-Max helicopter. Turn times averaged 1.7 minutes at an average yarding distance of 376 m.

FERIC estimated the total cost of falling, helicopter yarding, and loading at \$71.68/m^3. Falling accounted for \$5.89/m^3 or 8% of the total cost. Loading and processing accounted for \$11.75/m^3 or 16% of the total cost. Helicopter yarding accounted for \$54.04/m^3 or 76% of the total harvesting cost. The Lama yarding cost totalled \$58.81/m^3, 11% higher than the K-Max's yarding costs of \$52.94/m^3.

Implementation

The results of this study reflect some of the operational challenges associated with harvesting with light-lift helicopters in a clearcut prescription in the interior of British Columbia during winter months. There are several important considerations for planners:

- *Effects of in-woods manufacturing on helicopter yarding.* It is important to carefully analyze the effects of in-woods manufacturing on overall harvesting cost before committing to a processing/ bucking framework. While falling productivity increases and cost decreases as the level of in-woods manufacturing decreases, the reverse is true for helicopter yarding productivity and cost which generally represents a significantly higher proportion of the total harvesting cost.
- *Effects of a two-pass harvesting system.* Two-pass harvesting affected both falling and yarding phase productivity. It is important to evaluate the suitability of two-pass harvesting in relation to a site's piece size distribution. In this study, the K-Max was better suited to the cutblock's piece size. Using the Lama resulted in reducing the piece size blend available to the K-Max, which lead to production penalties. Two-pass harvesting is generally most suited to areas that have two or more distinct tree or piece size categories, and where the use of only one lift-category helicopter would be impractical or inefficient. In situations where two-pass harvesting is appropriate, it is important to select yarding helicopters with capabilities that match the characteristics of the site and stand.
- *Effects of seasonal timing on the operation.* In this study, poor weather resulting from conducting yarding operations during December and January accounted for an overall loss of 13% of total potential flight time. According to Airlift Helilog, weather-related downtime usually accounts for 15% or more of scheduled operating time in December and January. Scheduling yarding operations for the late fall or early spring to avoid heavy snowfalls, but still take advantage of cooler temperatures required to contain bark beetle spread, would have reduced snow loading on logs and associated weather downtime.
- *Effects of landing location.* In this study, re-locating Landings 1 and 3 could have significantly reduced turn times and eliminated potential safety concerns without adding much difficulty or expense. It is important to consider the effects of flight distance and flight path slope gradient on yarding productivity while also keeping in mind the other implications dramatic turn time reductions can have. Field engineers should look for opportunities to minimize flight distance while not exceeding flight path slope gradients of 35–40%. Furthermore, field engineers should ensure safety issues are recognized and addressed prior to the start of harvesting.
- *Effect of using only one log loader.* Having only one loader on site during the K-Max operation resulted in landing congestion and often lead to in-shift helicopter downtime. Planners should ensure the landing equipment complement is adequate to handle the volume being yarded.

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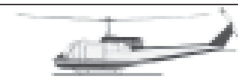
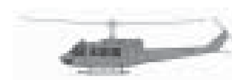
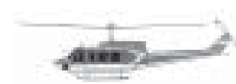
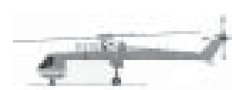
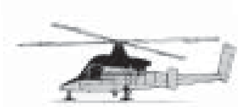
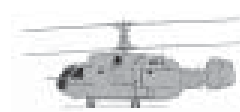
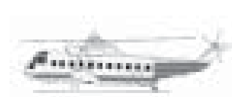
Appendix I

Specifications for helicopters commonly used for logging in B.C.[a]

Manufacturer	Model	Rated payload capacity (lb.)	Engines (no.)	Engine power[b] (kW)	Diameter main rotor (m)	Diameter tail rotor (m)	Diagram
Bell	204B	4 000	1	820	14.6	2.6	
Bell	205A	5 000	1	1 044	14.6	2.6	
Bell	212	5 000	2	671 (each)	14.7	2.6	
Bell	214B	8 000	1	2185	15.2	2.6	
Boeing	V-107 II	10 500	2	932 (each)	15.5	n/a	
Boeing	CH-234LR	28 000	2	3 039 (each)	18.3	n/a	
Sikorsky[c] Sikorsky[c]	S-64E S-64F	20 000 25 000	2 2	3 356 (each) 3 579 (each)	22.0 22.0	5.0 5.0	
Eurocopter	**SA-315B Lama**	**2 500**	**1**	**640**	**11.0**	**1.9**	
Kaman	**K-1200 K-Max**	**6 000**	**1**	**1 342**	**14.7 (×2)**	**n/a**	
Kamov	KA-32A	11 000	2	1 645 (each)	15.9 (×2)	n/a	
Sikorsky	S-58T	5 000	2	700 (each)	17.1	2.9	
Sikorsky Sikorsky	S-61N S-61N Shortski	8 000 9 000	2 2	1 044 (each) 1 044 (each)	18.9 18.9	3.2 3.2	

[a] Helicopter capabilities will vary with flight conditions and installed options.
[b] Engine power at takeoff.
[c] Now manufactured by Erickson Air-Crane Inc.

Appendix II

Helicopter costs [a] ($/flight-hour)

	SA-315B Lama	K-1200 K-Max	Support helicopter
OWNERSHIP COSTS			
Total purchase price (P) $	780 000	5 740 000	440 000
Expected life (Y) y	10	10	10
Expected life (H) h	27 470	27 470	12 000
Scheduled hours/year (h) = (H/Y) h	2 747	2 747	1 200
Net flight-hours/year (fh) h	2 194	2 194	962
Salvage value as % of P (s)	50	50	50
Interest rate (Int) %	9	9	9
Insurance rate (Ins) %	12	12	12
Salvage value (S) = ((P•s)/100) $	390 000	2 870 000	220 000
Average investment (AVI) = ((P+S)/2) $	585 000	4 305 000	330 000
Loss in resale value ((P-S)/(fh•Y)) $/flight-hour	17.78	130.81	22.87
Interest ((Int•AVI)/fh)/100 $/flight-hour	24.00	176.60	30.87
Insurance ((Ins•AVI)/fh)/100 $/flight-hour	32.00	235.46	41.16
Total ownership costs (OW) $/flight-hour	73.78	542.87	94.90
ANNUAL OPERATING COSTS			
No. of pilots required for the operation (pil)	2.5	2.5	1
Annual pilot base salary (PS) $/y	36 000	38 400	36 000
Annual flight-hours/pilot (pilh) h/y	878	878	962
Pilot flight-hour rate (pil$) $/h	35	35	35
Annual pilot flight pay (PF) = (pilh•pil$) $/y	30 730	30 730	30 730
Wage benefit loading (WB) %	45	45	40
No. of engineers (eng) [b]	2.5	2.5	n/a
Engineer salary (ES) $/y	51 000	51 000	n/a
Fuel consumption (F) L/flight-hour	240	370	113
Fuel [c] (fc) $/L	0.55	0.55	0.55
Oil as a % of fuel (fp) %	3	3	3
Annual parts inventory (Inv) = % of P	2.5	2.5	2.5
Wages for the operation, including fringe benefits			
Pilots (((PS•pil)+(pil$•pilh•pil)/fh)• (1+(WB/100))) $/flight-hour	110.25	114.22	101.39
Engineer ((ES•(1+WB/100))•eng)/fh $/flight-hour	84.26	84.26	n/a
Total wages (W) $/flight-hour	194.51	198.48	101.39
Fuel (F•fc) $/flight-hour	132.00	203.50	62.15
Oil ((fp/100)•(F•fc)) $/flight-hour	3.96	6.11	1.86
Maintenance of non-dynamic and non-life limited parts $/flight-hour	326.76	483.81	187.20
Maintenance of dynamic and life limited parts $/flight-hour	202.44	217.37	52.80
Parts inventory ((Inv/100)•(P/fh)) $/flight-hour	8.89	65.41	11.43
Miscellaneous ($/flight-hour)	4.51	9.44	7.50
Total operating costs (OP) $/flight-hour	873.07	1 184.12	424.33
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/flight-hour	946.85	1 726.99	519.23

[a] These costs are based on FERIC's standard costing methodology for determining machine and ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company.

[b] Number of engineers for the K-Max helicopter was assigned at two rather than one because this is a more typical engineering crew complement for this helicopter.

[c] Includes cost of transporting fuel to remote locations.

Appendix III

Machine costs
($/scheduled machine hour (SMH), excluding labour)

	Hydraulic log loader 31-tonne class
OWNERSHIP COSTS	
Total purchase price (P) $	500 000
Expected life (Y) y	10
Expected life (H) h	14 400
Scheduled hours/year (h)=(H/Y) smh	1 440
Salvage value as % of P (s) %	30
Interest rate (Int) %	9
Insurance rate (Ins) %	3
Salvage value (S)=(P•s/100) $	150 000
Average investment (AVI)=((P+S)/2) $	325 000
Loss in resale value ((P-S)/H) $/h	24.31
Interest (((Int/100)•AVI)/h) $/h	20.31
Insurance (((Ins/100)•AVI)/h) $/h	6.77
Total ownership costs (OW) $/h	51.39
OPERATING COSTS	
Fuel consumption (F) L/h	25
Fuel (fc) $/L	0.75
Lube and oil as % of fuel (fp) %	15
Annual repair and maintenance (Rp) $	37 500
Fuel (F•fc) $/h	18.75
Lube and oil ((fp/100)•(F•fc)) $/h	2.81
Repair and maintenance (Rp/h) $/h	26.04
Total operating costs (OP) $/h	47.60
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) $/h	98.99