WOOD HARVESTING

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FERIC

WINTER GRAPPLE YARDING IN THE INTERIOR OF BRITISH COLUMBIA

Dennis Araki, R.P.F.

Abstract

During the winter of 1991-92, the Forest Engineering Research Institute of Canada (FERIC) studied the performance of a Cypress 6280 swing yarder. The objectives were to determine the productivity and costs associated with the yarder harvesting trees in winter conditions in the Interior of British Columbia. Evaluations were conducted on the grapple yarding of both windrowed and non-windrowed handfelled timber.

Introduction

Historically, timber on gentle terrain in the Interior of British Columbia has been harvested with conventional ground-based systems. However, when ground-based equipment is used to harvest timber on steeper, more rugged slopes, both harvesting costs and environmental impacts increase. Although highlead yarding systems can reduce environmental impacts on steeper slopes, the costs are greater than for ground-based harvesting methods because of lower productivities relative to the capital invested. In addition, highlead methods are less effective during winter operations than ground-based systems because felled trees that are buried in snow are missed. The cost to relog these stems during snow-free periods is high.

A swing yarder with a grapple and a mobile backspar has the potential to overcome some of the limitations of a highlead system. Although the capital cost is high, production is less dependent on the efficiency of the large rigging crew (4) associated with the highlead system. Further, windrowing felled timber prior to grapple yarding has the potential to increase turn size, reduce log breakage and crew size, and extend the operating season.

During the winter of 1991-92, the Forest Engineering Research Institute of Canada (FERIC) evaluated a Cypress 6280 swing yarder owned by Tolson Enterprises Ltd. and working for Northwood Pulp and Timber Limited east of Prince George, British Columbia. The objective of the study was to determine the costs and productivities associated with grapple yarding windrowed and non-windrowed handfelled timber. This grapple-yarding system is one in a series of cable-yarding systems operating in the Interior of British Columbia to be studied by FERIC (Moshenko 1991; Forrester 1993).

Study Methods

Machine utilization and productivity data were collected using two methods of timing. DSR Servis recorders were mounted on the yarder and the hydraulic loader to record shift-level machine activity data on charts installed by the operators. In addition, the yarder operators recorded the number of stems yarded per shift and the reasons for any machine delays longer than 10 minutes. The volume of logs produced during the shift-level study was determined from the mill's weigh-scale records. The shift-level data were then compiled and analysed to provide machine productivity, availability, and utilization rates.

Detailed-timing data were collected periodically throughout the shift-level study period. This was accomplished by a FERIC researcher observing the work cycle elements and then recording their duration by

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Author: Dennis Araki is a Senior Researcher in the Harvesting Operations Group at FERIC's Western Division.

INSTITUT CANADIEN DE RECHERCHES EN GENIE FORESTIER
FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA

580 boul. Saint-Jean
Pointe Claire, Québec
Canada H9R 3J9
(514) 694-1140

2601 East Mall
Vancouver, B.C.
Canada V6T 1W5
(604) 228-1555

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entering event codes into a hand-held data logger. Additional data describing the logs yarded, such as butt-diameter class, were also recorded. The data logger files were later transferred to a microcomputer for analysis. Cycle elements, events, and log parameters are described in Appendix I. Butt-diameter classes were divided into 10-cm increments.

Using incremental butt-diameter classes to estimate volume is more accurate than using a single overall stem volume. The average volume per stem in the individual diameter classes was determined by measuring a sampling of stems in each diameter class to a 10-cm top. Volumes derived by FERIC were used to compare the relative productivity of the swing yarder during the detailed-timing segment and are not representative of the average volume for the whole block.

Soil disturbance surveys were conducted by Northwood Pulp and Timber's personnel, and the data summaries were provided to FERIC.

Site and System Descriptions

The study was conducted on two adjacent blocks in the Upper Torpy drainage east of Prince George. The individual cutblock areas were 33 and 93 ha in size, and slopes ranged from 25 to 65%. Both blocks contained sub-alpine fir and white spruce with an average butt diameter of 40 cm and an average tree volume of 1 m^3. The stands were representative of Central Interior, open-grown, over-mature sub-alpine fir and spruce, and contained some large snags, a significant volume of windfall, and an understory of immature sub-alpine fir. The presence of devil's club and Sitka alder on the study blocks indicated the site was very wet during most of the year. During the study, frequent snow storms occurred and snow depth was always greater than 1.3 m.

The timber on the smaller block and a portion of the timber on the larger block was handfelled and grapple yarded without windrowing because the terrain was too steep. On the remaining portion of the larger block, a Thunderbird 940 hydraulic loader windrowed stems for the Cypress 6280 swing yarder and hoe forwarded to roadside any stems within 20 m of the roadside. The yarding crew included an engineer and a spotter.

While the Cypress 6280 swing yarder can work in highlead, choker, and dropline yarding, as well as in variations of skyline yarding, in this study FERIC observed it only grapple yarding. The Cypress 6280 swing yarder studied (Figure 1) weighed approximately 57 000 kg. The boom height was 18 m and the gantry height was 12.7 m. The machine was capable of yarding up to 600 m with a maximum bare-drum line pull of 29 500 kg. The yarding equipment also included

Figure 1. Cypress 6280 swing yarder operating in winter conditions near Prince George.

a Mitsubishi MS 120 excavator as a mobile backspar, and a Caterpillar D8 tractor as a mobile guyline anchor. A Hitachi hydraulic log loader put the yarded stems onto off-highway logging trucks that transported them 5 km to a sortyard where buckermen manufactured the stems into logs; the logs were then reloaded onto off-highway log trucks. FERIC monitored only the grapple yarder performance during this study.

Results and Discussion

The study period extended from November 18, 1991 to January 24, 1992. A total volume of 21 370 m^3 of manufactured logs were weigh-scaled at the sawmill.

Shift-Level Study of the Cypress 6280 Swing Yarder

The contractor scheduled the yarding equipment to work two 11-h shifts per day. One operator worked 6 days/week while the other would work 14 consecutive days and then take a week off. There were 138 potential shifts during the 69-day study period, of which 64 shifts recorded production and 74 shifts recorded none. Of the latter, two shifts were lost waiting for parts, and two shifts were lost waiting for fallers to fell more timber. The remaining 70 nonproductive shifts were related to an extended Christmas shutdown, weekends, and the operators' scheduled time off.

The Cypress 6280 yarder had a mechanical availability of 86.1 and 92.6%, with a utilization rate of 79.3% and 89.8% for the two respective study units (Table 1).

On the non-windrowed area, the average productivity was 17.3 stems/SMH, or 23.2 m^3/SMH. The deep snow and the presence of Sitka alder made walking difficult and increased the time the hooktender spent looking for logs. The snow and the wet hillside also made it difficult for the guyline anchor machine to manoeuvre on the block where no trails were preconstructed.

Table 1. Shift-Level Timing: Summary for Swing Yarder

Description	Non-windrowed Total	Non-windrowed %	Windrowed Total	Windrowed %
Productive machine hours (PMH)				
Yarding (h)	200.7	58.7	239.8	77.6
Road and guyline changes, and wait for spotter (h)	70.4	20.6	37.8	12.2
Subtotal (h)	271.1	79.3	277.6	89.8
Mechanical delay hours (MDH)				
Repairs (h)	36.3	10.6	11.9	3.8
Service and warmup (h)	11.1	3.2	11.0	3.6
Subtotal (h)	47.4	13.8	22.9	7.4
Nonmechnical delay hours (NDH)				
Operational (h)	17.3	5.1	1.8	0.6
Organizational (h)	5.9	1.8	6.8	2.2
Subtotal (h)	23.2	6.9	8.6	2.8
Scheduled machine hours (SMH) (h)	341.7	100.0	309.1	100.0
Utilization (PMH/SMH) (%)	79.3		89.8	
Mechanical availability ((SMH-MDH)/SMH) (%)	86.1		92.6	
Total stems yarded (no.)	5 912		10 068	
Volume produced (m^3)	7 933		13 437	
Shifts with production (no.)	33		31	
Productivity				
Stems/PMH	21.8		36.3	
Stems/SMH	17.3		32.6	
Stems/8-h shift	138.4		260.6	
m^3/PMH	29.3		48.4	
m^3/SMH	23.2		43.5	
m^3/8-h shift	185.6		347.8	

Relatively long road change delays occurred in the non-windrowed area because the backspar and guyline anchor machine had difficulty moving across the block. Moving time included the length of time taken by the hooktender to walk from the yarding site to the guyline anchor machine or backspar and complete the move, the time the backspar excavator spent clearing stems along the trail and placing them under the grapple lines, and the time the guyline anchor machine spent constructing an access trail. Employing a second hooktender in the non-windrowed area might have reduced the long move times and increased yarding productivity.

The productivity on the windrowed area was almost double that of the non-windrowed area. The productivity was 32.6 stems/SMH, or 43.5 m^3/SMH. Also, the loader aligned and decked stems that were within 20 m of the logging road, and cleared the stems from the backspar trail and positioned them for grappling. When the operator moved the swing yarder to a new yarding road, he did not spend any time preparing the decking area at the road edge because the loader had already aligned and decked this wood. The loader was also used to hoe forward some stems from poor deflection areas to under the grapple lines. This improved yarding productivity because fewer hang-ups occurred and fewer equipment moves were required.

Four percent less mechanical delay time occurred when yarding windrowed stems than non-windrowed stems (Table 2). This improved mechanical availability was probably the result of a complete servicing to the yarder during the Christmas shutdown period.

Mechanical delays that occurred during yarding of non-windrowed stems included splicing the mainline cable and changing the grapple closing lines. The non-mechanical delays experienced were backspar excavator breakdowns, building of backspar and guyline anchor machine trails, and freeing stuck machines.

Yarding in the windrowed area required the spotter to only position the backspar over a new row of stems because the trails were preconstructed and clear of any felled trees. The organizational delays included waiting for the fallers, and carrying fuel and oil to the backspar excavator.

Table 2. Shift-Level Delays: Summary for Swing Yarder

Description	Non-windrowed Occurrences (no.)	Non-windrowed Time (h)	Non-windrowed %	Windrowed Occurrences (no.)	Windrowed Time (h)	Windrowed %
Mechanical delays						
Repairs						
Structural (excavator)	1	0.7				
Replace filters	3	2.9				
Tracks (main & auxiliary)				2	9.2	
Cables and/or chokers	13	14.9		1	0.4	
Air lines	2	3.6				
Hydraulics	3	7.1				
Electrical	2	4.2				
Structural (attachment)	2	2.9		1	2.3	
Subtotal	26	36.3	48	4	11.9	44
Service						
Service & oil changes	10	6.0		15	5.9	
Warmup	11	5.1		13	5.1	
Subtotal	21	11.1	15	28	11.0	41
Nonmechanical delays						
Operational						
Clear area for others	3	1.3				
Machine stuck	8	7.1		1	1.5	
Auxiliary equipment	10	8.9		1	0.3	
Subtotal	21	17.3	23	2	1.8	7
Organizational						
Other phases	2	4.6		1	0.4	
Move to new work area	2	4.5				
Shift change	4	1.3		4	1.9	
Subtotal	8	10.4	14	5	2.3	8
Total delays	76	75.1	100	39	27.0	100

During the yarding of the windrowed areas, two lengthy delays occurred when a track on both the yarder and the backspar excavator slipped off the rollers. Total equipment warmup, servicing, and oil change times were similar in both study areas.

Shift-Level Study of the Hydraulic Loader

The Thunderbird 940 hydraulic loader operated only during the day shift. A Servis recorder placed on the machine was damaged and therefore daily charts were not recorded. As a result, FERIC used the contractor's daily time sheets to estimate windrowing costs. The loader was used a total of 19 shifts from November 23 to December 20, and 14 shifts in January. The operator indicated that the Thunderbird loader worked approximately 8 h of the scheduled 11-h day during the study period.

Machine Costs

The ownership and operating cost calculations for the Cypress 6280 swing yarder, Mitsubishi excavator backspar, Caterpillar D8 guyline anchor machine, and Thunderbird 940 loader are presented in Appendix II. Based on the shift-level study data, the cost to yard the non-windrowed stems was $8.21/m^3 (Table 3). Although another, less expensive, excavator replaced the D8 as a guyline anchor machine, the hourly costs were estimated to be the same. The total cost to yard windrowed stems was $6.94/m^3, with the windrowing phase costing an estimated $2.55/m^3. The volumes yarded by the swing yarder in each of the study areas were determined by mapping the area windrowed and prorating the total volume equally over the 126-ha study area. All costs in this report were derived using FERIC's standard costing formula, and are not the actual costs incurred by the contractor.

Detailed-Timing Study of the Cypress 6280 Swing Yarder

Detailed-timing studies were conducted periodically during the shift-level studies. A total of 29.3 h of detailed-timing data were collected on the yarder working in the non-windrowed area while 16.5 h of data were collected on the windrowed areas (Table 4). The lengthy road changes (>10 min) in the non-windrowed area sig-

Table 3. Machine Costs: Summary

Equipment	Ownership and operating cost ($/h)	Non-windrowed Total time (h)	Non-windrowed Total cost ($)	Windrowed Total time (h)	Windrowed Total cost ($)
Cypress 6280 swing yarder	165.02	341.7	56 387	309.2	51 024
Mitsubishi backspar	12.79	341.7	4 370	309.2	3 955
Caterpillar D8 anchor	12.79	341.7	4 370	309.2	3 955
Thunderbird 940 loader	129.96			264.0	34 309
Total cost ($)		65 127		93 243	
Volume yarded (m^3)		7 933		13 437	
Cost/m^3 ($)		8.21		6.94	

nificantly reduced the yarding time. During detailed timing, data were collected on 1397 stems, which were all classified by butt diameter. The unmerchantable volume that was yarded is included in the detailed-timing summaries. Measurement of a sample of stems, including unmerchantable stems, in each of the butt-diameter classes allowed FERIC to estimate that 1122 m^3 of timber were yarded during detailed timing. Yarding productivity averaged 20.5 m^3/PMH on the non-windrowed portion, and 31.5 m^3/PMH on the windrowed area.

The breakdown of the timing elements recorded during the detailed-timing study is summarized in Table 5, and the timing elements are defined in Appendix I. Average cycle time was 2.12 min on the non-windrowed area, and 1.56 min on the windrowed portion. The average cycle time for the windrowed stems was shorter because the operator knew where to spot the next turn, grappling logs by the butts is easier, and less care is required to yard turns with butts forward. In addition, fewer road changes were needed because the windrowed stems were piled along specific yarding roads, rather than scattered over the yarding lane, and the spotting time for merchantable stems or pieces was substantially reduced. Conversely, decking time increased slightly because more stems were yarded along each yarding road.

On the non-windrowed area the deep snow conditions made it difficult for the crew to assess the merchantability of snags and windfalls. As a result, a large amount of unmerchantable volume was yarded to roadside to ensure no merchantable volume was left unyarded. However, on the windrowed area, the percentage of snag material and the number of broken tops yarded were both reduced (Table 6) because the excavator operator inspected all the stems he handled and placed only the merchantable ones into the windrow. Windrowing stems prior to yarding also reduced stem breakage during yarding because the stems were not tangled together and because the log butts were aligned to the yarding corridor. With conventional grapple yarding, the operator frequently grapples the stem by the top, which can result in breakage during inhaul if hang-ups occur along the yarding road. Small stems and broken tops from falling were bunched together or placed with larger stems in the windrows to maximize turn size. Yarding windrowed tree-length stems not only improved productivity, but reduced the occurrence of log breakage. It would be expected that reduced log breakage would in turn increase fibre recovery during manufacturing.

Other Observations

Site Disturbance

The terrain and stand conditions on the windrowed area were similar to those on the non-windrowed area. The Pre-Harvest Silvicultural Prescription indicated the blocks had a medium soil sensitivity rating and stipulated the blocks should be harvested during the winter season. The maximum allowable level of soil disturbance was 20%. Northwood's post-harvest soil-disturbance survey identified that all disturbance categories fell well below the maximum allowable, with a total site disturbance of 5.4% (Table 7). Yarding disturbance was particularly light because the deep snow conditions prevented logs from scalping the soil during yarding.

Extended Operating Period

Using a loader to windrow felled stems during the winter not only extends the yarding season into periods of heavy snowfall, but also allows the falling and yarding phases to be scheduled further apart. Lengthening the operating season allows the equipment owner to amortize capital investment over a longer working season and in turn reduce the overall yarding cost.

Table 4. Detailed-Timing: Summary of Productive Machine Hours

Description	Non-windrowed Time (min)	Non-windrowed %	Windrowed Time (min)	Windrowed %
Productive time				
Yarding	934.9	53.1	598.9	60.6
Road changes <10 min	313.1	17.8	193.4	19.6
Delays <10 min	25.0	1.4	16.3	1.6
Road changes >10 min	486.0	27.7	180.0	18.2
Total productive time (min)	1759.0	100.0	988.6	100.0
Productive machine hours (PMH) (h)	29.3		16.5	
Yarding distances				
Maximum (m)	200		200	
Average (m)	100		100	
Merchantable stems (no.)	588	88.3	681	93.2
Nonmerchantable stems (no.)	78	11.7	50	6.8
Total stems (no.)	666	100.0	731	100.0
Merchantable volume (m^3)	511	84.9	461	88.7
Nonmerchantable volume (m^3)	91	15.1	59	11.3
Total volume (m^3)	602	100.0	520	100.0
Total cycles (no.)	602		517	
Total stems/cycle (no.)	1.1		1.4	
Total volume/cycle (m^3)	1.0		1.0	
Stems/PMH (no.)	22.7		44.3	
Volume/PMH (m^3)	20.5		31.5	

Table 5. Breakdown of Cycle Time Elements

Activity	Non-windrowed Time/cycle (min)		Non-windrowed %	Windrowed Time/cycle (min)		Windrowed %
Outhaul	0.39		18.4	0.34		21.8
Hookup	0.38		17.9	0.27		17.3
Inhaul	0.45		21.2	0.37		23.7
Deck[a]	0.04	(0.48)	1.9	0.06	(0.70)	3.8
Spot[a]	0.21	(1.79)	9.9	0.03	(0.98)	1.9
Move yarder and/or anchor[a]	0.11	(2.94)	5.2	0.09	(3.79)	5.8
Move backspar[a]	0.41	(3.72)	19.3	0.28	(5.33)	17.9
Delay[a]	0.04	(4.17)	1.9	0.03	(5.40)	1.9
Abort[a]	0.09	(2.22)	4.3	0.09	(3.73)	5.9
Total time	2.12		100.0	1.56		100.0

[a] This element did not occur on every cycle, but the value shown is the average applied to all the cycles. Bracketed number is the average time per occurrence.

Table 6. Production: Summary for Swing Yarder

Description	Non-windrowed Stems (no.)	Non-windrowed %	Windrowed Stems (no.)	Windrowed %
Merchantable stems	463	69.5	645	88.2
Broken tops	125	18.8	36	4.9
Snags and windfall	78	11.7	50	6.9
Total stems	666	100.0	731	100.0

Table 7. Site Disturbance Surveys: Summary[a]

Type of disturbance	Measured level (%)	Maximum allowable[b] (%)
Roads and landings		
Roads	3.5	
Landings	-	
Total	3.5	7.0
Other disturbances		
Fire guards	-	
Skidding disturbance	0.4	
Backspar trails	1.5	
Total	1.9	13.0
Total site disturbance	5.4	20.0

[a] Data provided by Northwood.
[b] Maximum allowable site disturbance levels as specified by the *Soil Conservation Guidelines for Timber Harvesting - Interior British Columbia* (British Columbia Ministry of Forests 1993).

Other Potential Savings

Although the stems were not processed at roadside in this study, windrowing would improve roadside processing because all the stems were yarded with butts ahead. In addition, more efficient loading and less breakage occurred when all the butts were decked at roadside.

Summary and Conclusions

During the winter of 1991-92, FERIC evaluated the operation of a Cypress 6280 swing yarder and compared the productivities and costs of yarding non-windrowed and windrowed handfelled timber. The study was undertaken in the Interior of British Columbia with cooperation from Northwood Pulp and Timber Limited.

The shift-level study showed the Cypress 6280 had an overall availability of 89.2%, and was utilized 84.4% of the time. The swing yarder's productivity improved from 23.2 m^3/SMH in the non-windrowed area to 43.5 m^3/SMH in the windrowed area. Based on FERIC's machine cost analysis, yarding costs were \$8.21/m^3 and \$6.94/m^3 on the non-windrowed and windrowed areas, respectively.

Deep snow conditions encountered during the study reduced productivity on the non-windrowed area; the spotter found it difficult and slow to walk the yarding road to check for merchantable stems, or to walk to the backspar and anchor machine to change yarding roads. Windrowing handfelled stems improved yarding productivity by increasing the turn sizes, reducing breakage, and reducing the percentage of unmerchantable stems yarded. In addition, windrowing reduced the number and duration of yarding road changes, and the amount of time required to direct the yarder operator to a grapple turn.

The loader helped reduce breakage and improve merchantability by aligning the stems so they could be yarded with butts ahead, and less breakage occurred during the loading phase because the hydraulic log loader picked up the stems near the butt.

References

British Columbia Ministry of Forests. 1993. *Soil Conservation Guidelines for Timber Harvesting - Interior British Columbia*. Victoria. 6p.

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

Moshenko, Darcy W. 1991. *Grapple Yarding in the Interior of British Columbia*. Vancouver: FERIC. Technical Note TN-176. 10p.

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Disclaimer

APPENDIX I

Definitions

Timing Elements

outhaul - Time taken for the grapple to travel from the roadside deck until it stops at the target stem(s).

hookup - Time taken for the grapple to open, drop onto and secure the target stem(s).

inhaul/unhook - Time required for the secured stem(s) to be moved from the block to the roadside and dropped on the deck.

deck - Time associated with the yarder moving stem(s) already on the log deck, e.g. straightening or redecking.

move yarder - Time taken by the crew to move the yarder and/or the anchor machine into a new position; includes walking time of the hooktender.

move backspar - Time taken by the hooktender to move the backspar into a new position; includes walking time of the hooktender.

spot - Time taken for the hooktender to check a yarded row for merchantable stems.

sumtime - Total cycle time from the start of outhaul to the end of inhaul when individual element times were missed.

delay - Time when the yarder, backspar, or anchor machine was not actively involved in yarding logs.

abort - Occurs when the engineer or hooktender determines a stem to be unmerchantable; the grapple drops the stem and returns to grapple another.

APPENDIX II

Machine Costs: Swing Yarder, Excavator Backspar, Guyline Anchor, and Loader

	Cypress 6280 swing yarder	Mitsubishi excavator backspar	Caterpillar D8 guyline anchor	Thunderbird 940 loader[c]
OWNERSHIP COSTS				
Purchase price (P) ($)	800 000	60 000	60 000	557 000
Expected life (Y) (yr)	12	3	3	5
Expected life (H) (h)	43 200	10 800	10 800	15 000
Scheduled hours per year (h) (h)	3 600	3 600	3 600	3 000
Salvage value as % of P (s) (%)	30	20	20	20
Interest rate (Int) (%)	12	12	12	12
Insurance rate (Ins) (%)	3	3	3	3
Salvage value (S) = ((s•P)/100) ($)	240 000	12 000	12 000	111 400
Average investment (AVI) = ((P+S)/2) ($)	520 000	36 000	36 000	334 200
Loss in resale value = ((P-S)/H) ($/h)	12.96	4.44	4.44	29.70
Interest = ((AVI•Int/100)/h) ($/h)	17.33	1.20	1.20	13.37
Insurance = ((AVI•Ins/100)/h) ($/h)	4.33	.30	.30	3.34
Total ownership cost (OW) ($/h)	34.62	5.94	5.94	46.41
OPERATING COSTS				
Wire rope (wc) ($)	11 000			
Wire rope life (wh) (h)	900			
Rigging, grapple, and radio (rc) ($)	13000			
Rigging, grapple, and radio life (rh) (h)	6000			
Fuel consumption (F) (L/h)	50	5	5	50
Fuel (fc) ($/L)	0.42	0.42	0.42	0.42
Lube and oil as % of fuel (fp) (%)	15	15	15	15
Shift length (sl) (h)	11	8	-	-
Annual repair and maintenance[a] (Rp) (%)	53 333	16 000	16 000	89 120
Wages (W)				
Engineer ($/h)	22.00			22.00
Hooktender ($/h)	18.50			
Wage benefit loading (WBL) (%)	35			35
Line cost = (wc/wh) ($/h)	12.22			
Rigging, grapple, radio cost (rc/rh) ($/h)	2.17			
Repair and maintenance = (P•Rp/100)/H) ($/h)	14.81	4.44	4.44	29.70
Fuel (F•fc) ($/h)	21.00	2.10	2.10	21.00
Lube and oil = ((F•fc)•(fp/100)) ($/h)	3.15	.31	.31	3.15
Wages and benefits = (W•(1+WBL/100)) ($/h)	54.68			29.70
Prorated overtime = ((W•1.5)-W)•(sl-8)•(1+WBL/100))/sl) ($/h)	22.37			
Total operating cost (OC) ($/h)	130.40	6.85	6.85	83.55
TOTAL OWNERSHIP AND OPERATING COSTS[b] (OW+OC) ($/h)	165.02	12.79	12.79	129.96

[a] Annual repair and maintenance costs were estimated to be 80% of the equipment purchase price divided by its expected life.
[b] Costs are based on FERIC's standard costing methodology for determining comparative machine ownership and operating costs. These costs do not include supervision, profit and risk, or overhead allowances, and are not the actual costs incurred by the contractor.
[c] The expected life of the loader was significantly reduced to reflect its uses in rough terrain conditions.