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

TN #
56

An Evaluation of Highlead and Slackline Yarding with a Madill 046 Yarder

E.A. SAUDER

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201 - 2112 West Broadway, Vancouver, B.C., Canada V6K 2C8
143 Place Frontenac, Pointe Claire, Québec, Canada H9R 4Z7

FOREWORD

FERIC gratefully appreciates the assistance and cooperation of the crew and management of MacMillan Bloedel Chemainus Division. Particular thanks are extended to D. Johnson, P. Cottell, and B. Sauder for their time reviewing the draft. The author would like to thank P. Forrester for his field assistance during the study, P. Tse for computing assistance and R. Breadon for editorial assistance.

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SUMMARY AND CONCLUSIONS

This study provided an opportunity to compare the performance of a Madill 046 (4 drum) yarder rigged in highlead and slackline configurations. Yarding configuration was alternated from yarding road to yarding road so as to minimize the effect of terrain, timber size and crew performance.

Table S-1 summarizes the results.

TABLE S-1. Summary of Study Results.

	Yarding Configuration	
	Highlead	Slackline
Average yarding distance (m)	185	185
Net cycle time per turn (min)	5.65	6.83
Pro-rated road change time (min)	0.37	1.21
Productive time per turn (min)	6.02	8.04
Delay time per turn (min)	1.20	1.28
Total time per turn (min)	7.22	9.32
Number of pieces per turn	2.5	3.5
Total number of shifts observed	6.5	9.5
Average time per shift (hr)	7.4	7.7
Number of pieces yarded per shift	152	172
Number of turns yarded per shift	61	50
Total volume yarded (m^3)	1191	1975
Average volume per shift (m^3)	184	208
Yarding breakage		
Percent of yarded pieces broken	9	5
Percent of yarded volume broken	1.4	0.6
Escaped logs		
Percent of yarded pieces that escaped	15	6
Estimated yarding cost ($/$m^3$)	9.66	9.37

Study results are specific to this setting. However, the following conclusions are evident:

1) It was more economical to use the Madill 046 4-drum yarder to slackline rather than highlead log. While slackline yarding, a significant decrease in the number of hangups (and thus a decrease in corresponding delay time as a result of hangups) was observed. Yarding efficiency was also greater during slackline yarding, as considerably fewer logs escaped from the chokers during inhaul yarding compared to highlead yarding. The reduction in log escapes during slackline yarding resulted in less chance of breakage (as rechoked logs could be broken on breakout), more productive hook-up times (logs that were choked would arrive at the landing) and thus greater productivity per shift.

2) A 4-drum yarder should be used to highlead yard when:

   - individual yarding roads in a setting are **relatively** short (less than 180 m).
   - log quality will not be reduced as a result of yarding breakage (i.e. timber is mainly pulp quality).
   - ground obstacles will not prevent inhauled logs from hanging-up.
   - the small volume of wood per unit area does not permit the operation of a skyline yarding system.
   - there are not suitable skyline anchors.

3) Slackline yarding should be encouraged, especially when:

   - yarding distances exceed 215 m.
   - there are ground obstacles that could be cleared if a skyline were used.
   - log quality is high and yarding breakage is to be minimized.
   - skyline anchors can be located so that adequate deflection is provided.

SOMMAIRE ET CONCLUSIONS

La présente étude a permis de comparer la performance d'un téléphérique forestier Madill 046 (à 4 tambours) utilisé comme câble-grue à tension fixe et câble-grue à tension variable. Le mode de câblage alternait d'une travée à l'autre afin de minimiser l'effet du terrain, du diamètre des arbres et de la performance de l'équipe.

Le tableau S-1 offre un sommaire des résultats obtenus.

Les resultats de cette étude sont specifiques à ce site d'exploitation. Cependant, les conclusions suivantes sont évidentes:

1) Il fut plus avantageux d'utiliser le téléphérique forestier Madill 046 à 4 tambours pour débusquer comme câble-grue à tension variable que comme câble-grue à tension fixe. Lors du débusquage avec cable à tension variable, une diminution significative du nombre d'évènement d'accrochage (et par conséquent une diminution des temps de delais correspondant résultant des accrochages) fut observé. Le débusquage avec câble-grue à tension variable était aussi plus efficasse car moins de grumes furent échappées des crochets comparativement au débusquage avec câble-grue à tension fixe. La réduction du nombre de grumes échappées lors du débusquage à tension variable a resulté en une diminution des chances de bris (étant donné que les grumes accrochées de nouveau peuvent être brisées lorsque les cables sont remis sous tension) une meilleure productivité dans les temps d'instalation des crochets (les grumes instalées sur crochet se rendront à la jettée) et ainsi une meilleure productivité par quart.

2) Un câble-grue à 4 tambours devrait être utilisé comme débusqueuse à tension fixe lorsque:

   - les travées de débusquage individuelles d'un site d'exploitation sont relativement courtes (moins de 180 m).

   - la qualitée des grumes ne sera pas reduite dû aux bris de débusquage (i.e. principalement du bois à pâte).

TABLEAU S-1. Sommaire des résultats de l'étude.

	Mode de câblage	
	A tension fixe	A tension variable
Distance moyenne de téléphérage (m)	185	185
Temps net par rotation (min)	5.65	6.83
Temps proportionnel de changement de travée (min)	0.37	1.21
Temps productif par rotation (min)	6.02	8.04
Temps morts par rotation (min)	1.20	1.28
Temps total par rotation (min)	7.22	9.32
Nombre de grumes par rotation	2.5	3.5
Nombre total de postes de travail observés	6.5	9.5
Temps moyen par poste de travail (h)	7.4	7.7
Nombre de grumes débusquées par poste	152	172
Nombre de rotation par poste de travail	61	50
Volume total débusqué (m^3)	1191	1975
Volume moyen par poste (m^3)	184	208
Bris en cours de débusquage		
Pourcentage de grumes débusquées brisées	9	5
Pourcentage de volume débusquées brisées	1.4	0.6
Grumes échappées		
Pourcentage de grumes débusquées échappées	15	6
Estimation des coûts de téléphérage ($/$m^3$)	9.66	9.37

- les obstacles de terrain n'empêcheront pas les grumes débusquées de demeurer installées sur les crochets.

- un faible volume de bois par unité de surface ne permet pas l'opération d'un système de débusquage à tension variable.

- il n'y a pas d'encrage approprié pour le débusquage à tension fixe.

3) Le débusquage à tension fixe devrait être favorisé, spécialement lorsque:

- les distances de débusquage excèdent 215 m.

- il y a présence d'obstacles de terrain qui pourraient être surmontés si un câble-grue à tension variable était utilisé.

- la qualité des grumes est élevée et que les bris de débusquage doivent être minimisés.

- les encrages pour câble à tension fixe peuvent être situés de façon à obtenir une deflection adéquate.

INTRODUCTION

Slackline yarders, although designed to yard in a variety of skyline configurations, are periodically rigged for highlead yarding. It is more advantageous to use the slackline yarder rather than to bring in a highlead yarder and incur the additional set-up and take-down costs, when small portions of settings do not require a skyline's long reach or load suspension capability.

The ability to fully or partially suspend loads when slackline yarding was expected to:

- reduce log breakage
- reduce the number of logs that fell out of the turn during inhaul
- reduce ground disturbance.

MacMillan Bloedel Chemainus Division was particularly interested in determining how log breakage during slackline and highlead yarding compared. FERIC observed a Madill 046 slackline yarder rigged alternately for highlead and slackline on successive yarding roads in the same setting. FERIC's objectives were to report the productivity, delays and yarding breakage associated with each system.

If a slackline yarder had not been available for this particular setting, the scabline system (a modified highlead system where the butt rigging is supported by a block running on the haulback line) would have been used.

AREA

Figure A shows the setting during yarding. Figure B is a topographic map showing the location of highlead and slackline yarding roads, and Figure C shows typical yarding road profiles. Table 1 describes the characteristics of the setting. The timber was predominantly balsam (Abies amabilis) with lesser volumes of western hemlock (Tsuga heterophylla), western red cedar (Thuja plicata) and cypress (Chamaecyparis nootkatensis). Felling and bucking preceded yarding by one year. Log volumes were estimated to average 1.21 m^3 per log. All yarding was downhill.

FIGURE A. Highlead-Slackline Setting.

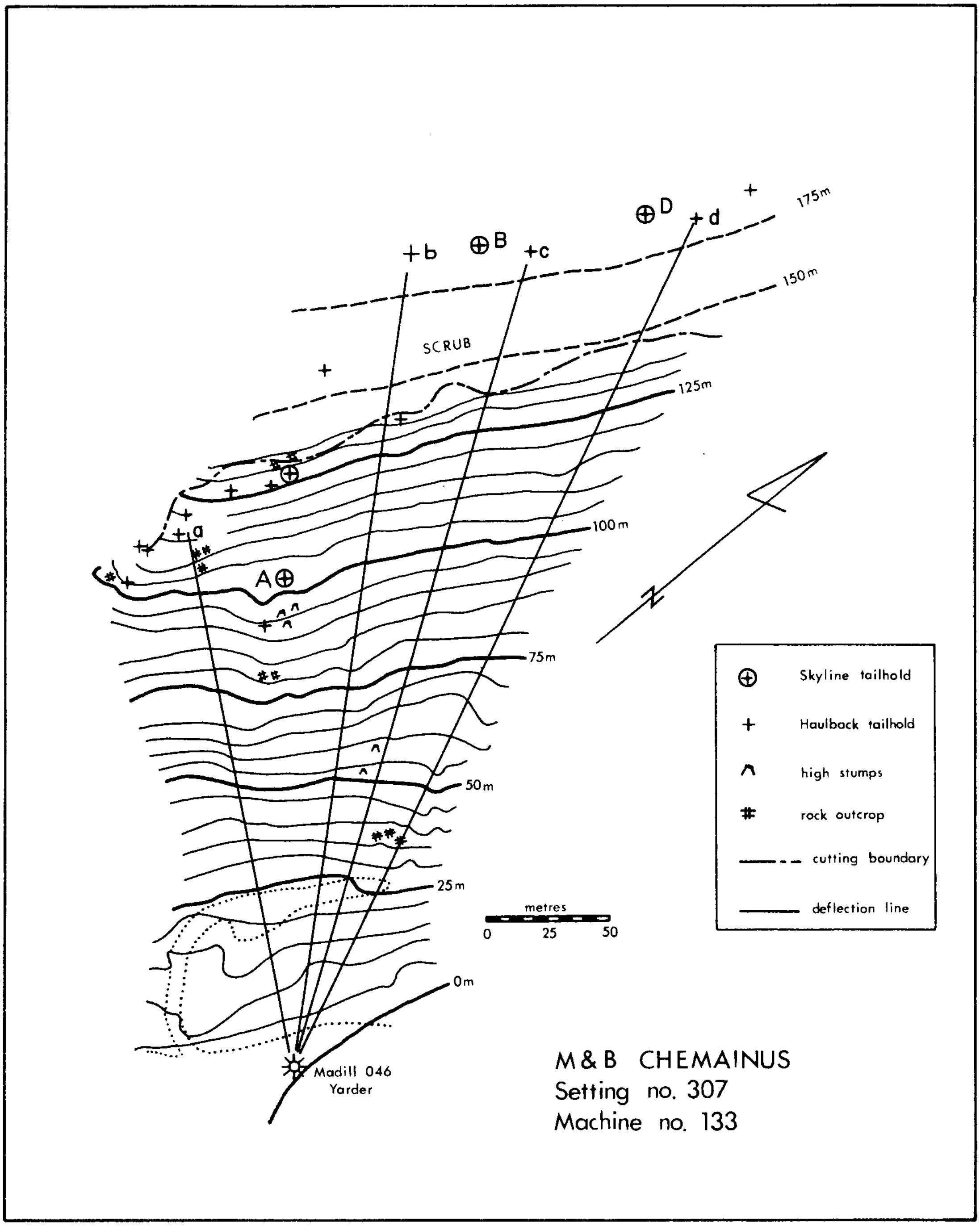


FIGURE B. Map of Highlead-Slackline Setting. (see Figure C for deflection line profiles)

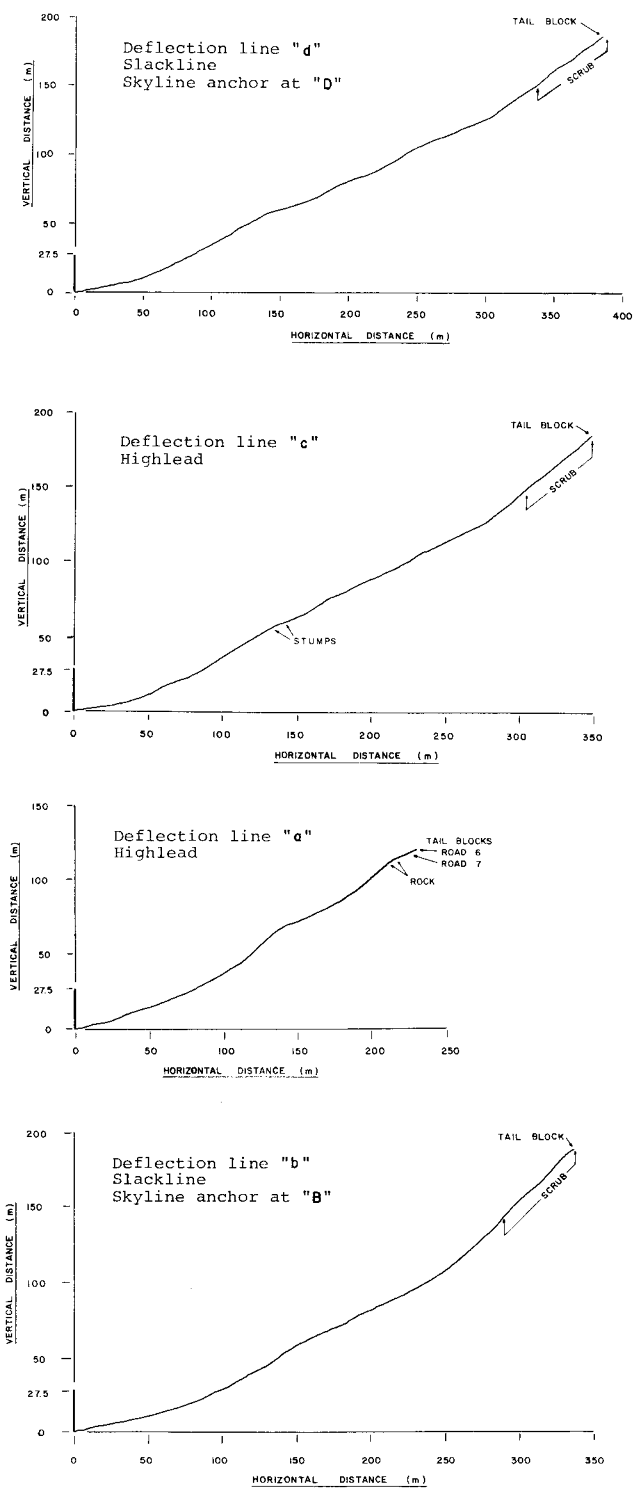


FIGURE C. Deflection Lines.

TABLE 1. Description of Study Area.

	Rigging Configuration: Highlead	Rigging Configuration: Slackline
Slope yarding distance		
- maximum external	320 m (1,050 ft)	290 m (950 ft)
- weighted average during study	185 m (605 ft)	185 m (605 ft)
Average downhill yarding slope	50%	50%
Deflection	Good	Fair
Operator visibility	Good	Good
Terrain	Moderate. Some rock outcrops and areas with abnormally high stumps.	
Timber species	Balsam with hemlock, cedar and cypress.	
Average log volume	1.21 m^3 (43 ft^3)	1.21 m^3 (43 ft^3)
Distribution of log volumes	volume limit (m^3)	cumulative % of total yarded pieces
	.01 to <.25	26
	<.50	45
	<1.00	65
	<2.00	82
	<3.00	90
	<4.00	94
	<5.00	96
	<6.50	98
	<11.50	100

YARDER

A Madill 046 was used during the study (Figure D), rigged alternately for highlead and for slackline at road changes. Table 2 summarizes the yarder characteristics.

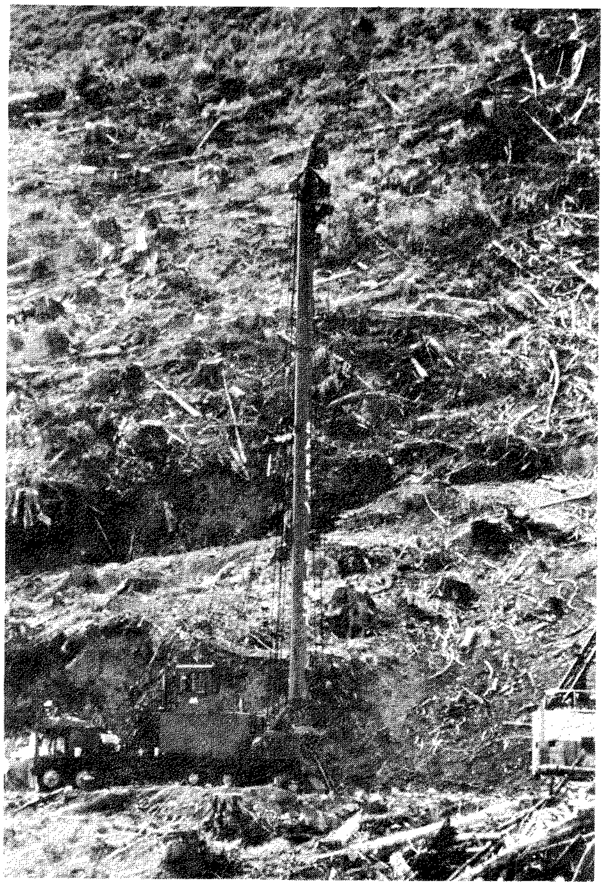


FIGURE D. Madill 046 Slackline Yarder.

TABLE 2. Madill 046 Specifications and Line Capacity.

Engine	GM 12V71-NTO (Mark 20) 600 kW (450 hp)			
Undercarriage	4-axle rubber-tired carrier			
Tower height	27.4 m (90 ft)			
Weight	55 800 kg (122,825 lb)			
Number of guylines	8			
Line Capacity:	diameter (mm)	length (m)	diameter (in.)	length (ft)
Skyline	35	580	1 3/8	1,900
Haulback	24	1370	15/16	4,500
Skidding (Mainline)	29	610	1 1/8	2,000
Strawline	11	1520	7/16	5,000

YARDING SYSTEMS: HIGHLEAD AND SLACKLINE

Highlead yarding requires a yarder with a mainline and a haulback drum. The haulback pulls the chokers out to the yarding crew, where chokers are attached to the logs. The mainline pulls the logs into the landing, where they are unhooked. (Studier and Binkley, 1974.)

Slackline yarding requires a live skyline that supports a simple carriage. A yarder with mainline, haulback and skyline drums is used. The haulback pulls the carriage out to the turn. The skyline is lowered, logs are choked; then the skyline is raised and the turn pulled into the landing with the mainline. Log ends can be raised, and some lateral yarding is possible depending on the haulback block placement (the skyline and carriage are pulled over as the skyline is slackened). Rigging for road changes can be time consuming and difficult. (Studier and Binkley, 1974.)

CREW

For each of the two systems, the crew consisted of:

	Rigging Configuration	
	Highlead	Slackline
Landing crew:		
yarder operator	1	1
landing bucker	1	1
chaser (landing man)	1	1
Yarding crew:		
rigging slinger	1	1
chokermen	1*	2
Back rigging crew:		
back rigger	1	1
back rigger helper	1	1
Hook and rig	1	1
Total crew:	8	9

*Crew allocated to other work sites resulted in only one chokerman during most of the highlead yarding.

During a conventional highlead operation, the backrigging crew would not be used.

The yarding crew used a radio "whistle bug" for signalling to the yarder operator and others. The backrigging crew used a portable radio for voice communication with the yarder operator.

YARDING PROCEDURE

Backrigging Crew

Highlead yarding utilized sturdy stumps (usually located along the setting perimeter) for haulback block tailholds. Slackline yarding required firm tailholds for the skyline (usually a standing tree tied back to other trees) and haulback tailblocks (stumps). Skyline anchors were located outside the setting perimeter so the loaded carriage could clear the ground during inhaul.

One (20 m high) back spar (that had been left fully rigged after being used to log the adjacent setting) was used during the study. The skyline was anchored to a stump after it passed through a block strapped to the top of the spar.

The backrigging crew pre-rigged skyline anchors (prepared twisters to tie-back trees) and haulback-block tailholds. Road change delays were minimized and lengthy delays occurred only when the skyline road was changed. Highlead roads generally made use of the slackline haulback tailholds, resulting in rapid highlead road change times.

Yarding Crew

On each new yarding road, the yarding crew started choking logs at the landing and worked to the setting perimeter, then returned to the landing picking up logs previously missed or that escaped during yarding. Side-blocking the carriage using the haulback resulted in wider slackline roads than highlead roads (Figure E). In addition, as a result of the extra ground clearance for the carriage and chokers occurring during slacklining, longer chokers could be used--12 m versus 9 m for highlead.

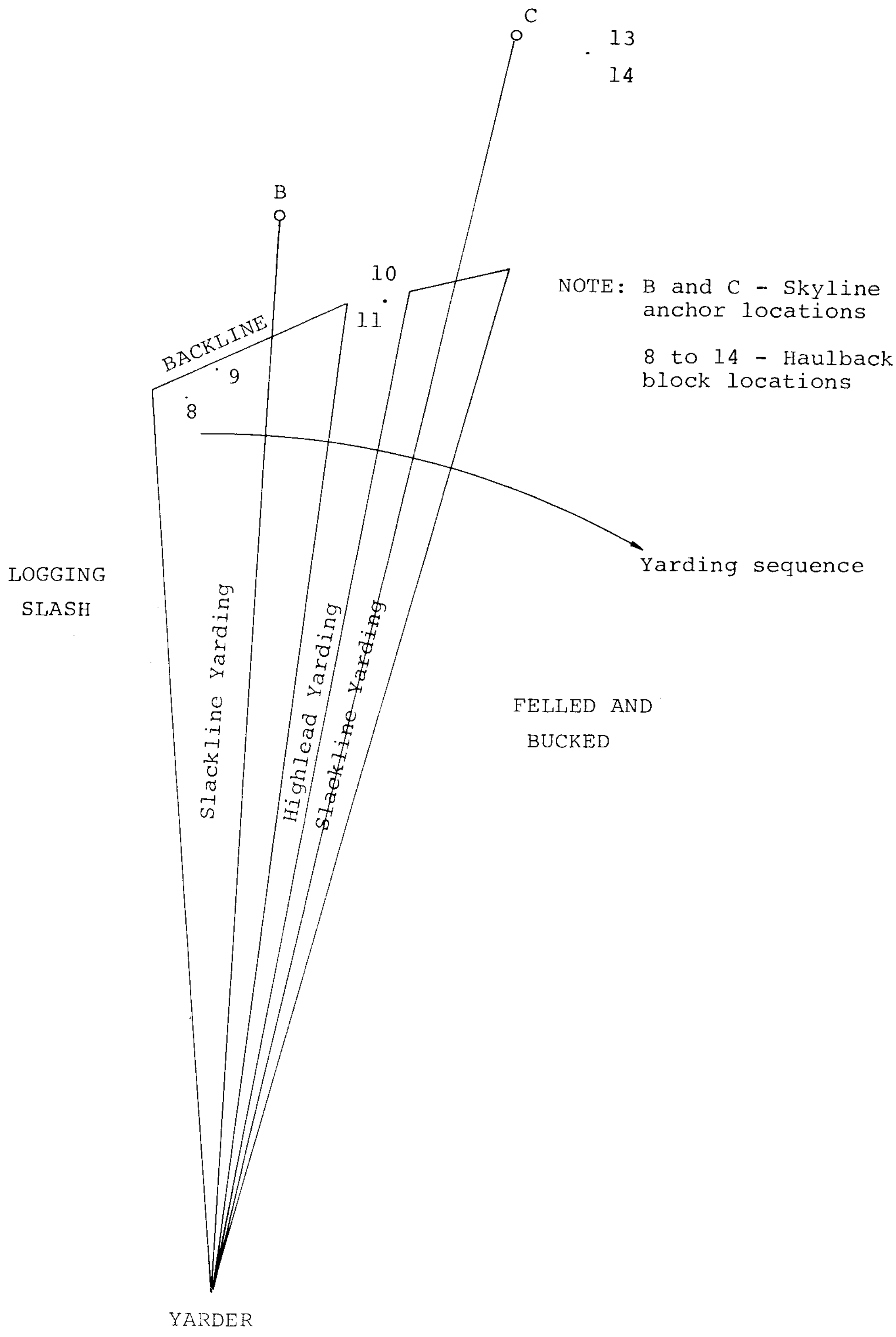


FIGURE E. Yarding Road Configurations.

Landing Crew

The chaser unhooked chokers from each turn. He also prepared strawline coils (for use during road changes), using a hand-powered reel mounted on the yarder frame (Figure F) and prepared supplies for the backrigging crew. Coils and supplies were sent to the backrigging crew either directly attached to the butt-rigging or in a drum carrier (the bottom half of a 200-litre oil drum).

A cable-operated grapple loader kept the decking area clear of logs, set aside logs that required trimming and loaded the log trucks.

The landing bucker trimmed broken ends from logs, bucked long logs and trimmed branches.

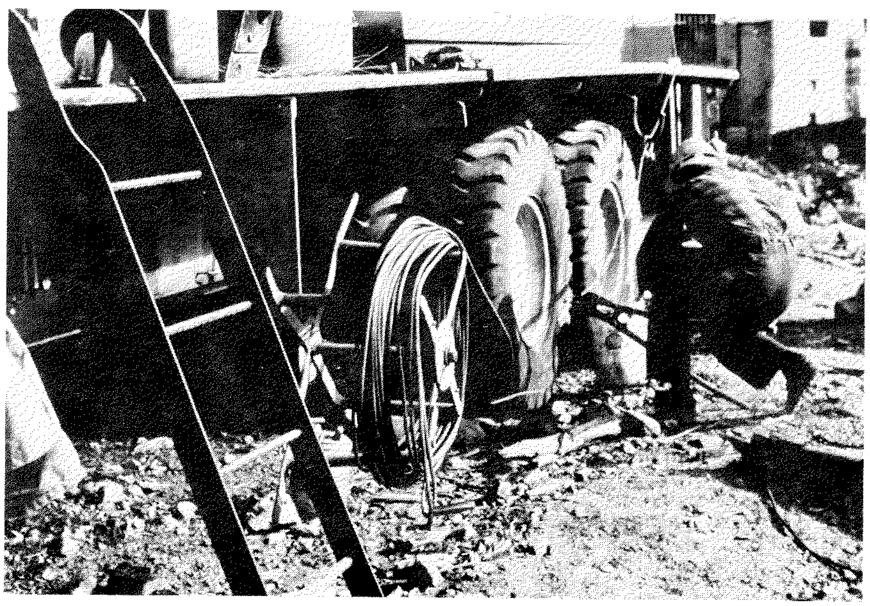


FIGURE F. Hand-Powered Reel For Coiling Strawline.

STUDY METHOD

The FERIC study lasted 6½ highlead and 9½ slackline shifts. On each yarding road, the slope distance from the yarder was marked in 30 m (100 ft) intervals. Elements of the yarding cycle (see categories in Appendix I) were timed for each turn, together with any delays that interrupted yarding. Road changes were also timed. Log sizes in each turn were estimated (and regularly check-scaled) to avoid interruption to the yarding cycle. Logs that broke or escaped from the choker during yarding were noted. Turn sizes were based on pieces arriving at the landing.

All information collected was designed to permit comparison of the two yarding systems for productivity, system delays and log breakage or escapements for various yarding distances.

STUDY RESULTS

YARDING CYCLE TIMES

The detailed timing results are summarized in Table 3 and the average time distribution by cycle element is shown in Figure G.

With similar average yarding distances, every cycle time element averaged longer for slackline than for highlead. Many of the differences were found to be statistically significant.

The following reasons may explain the increased cycle times for slackline yarding (compared to highleading):

Outhaul: slackline carriage required time to raise and lower, and extra time was incurred to side block carriage.

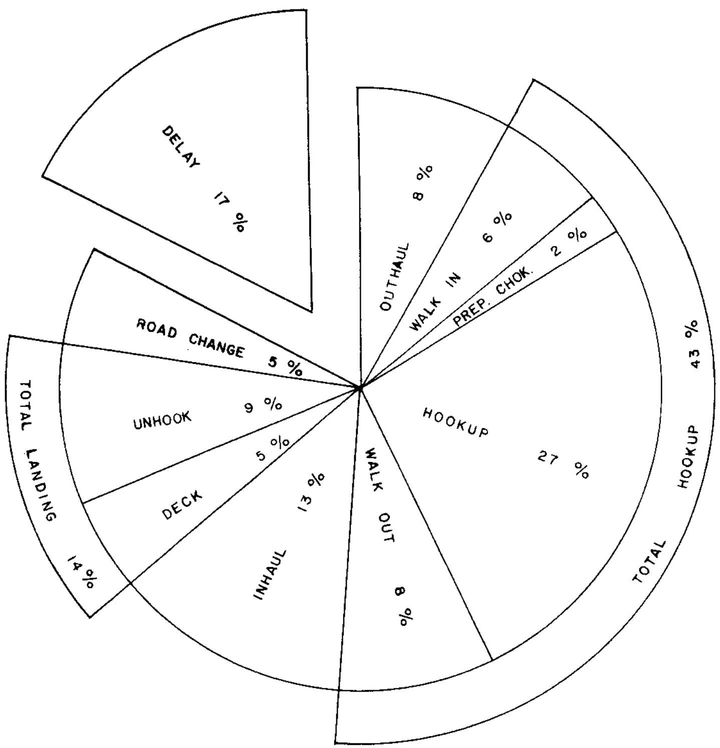
Walk In and Walk Out: wider roads and a greater number of logs per turn required the crew to walk further to safe observation areas.

TABLE 3. Summary of Average Turn Times.

	Rigging Configuration				Result of T-Test on Means(1)
	Highlead		Slackline		
Average yarding distance (m)	185		185		
Number of turns yarded	396		473		
Number of pieces per turn	2.5		3.5		
Average times per turn (min)					
Outhaul		.60		.67	*
Walk in	.42		.57		**
Prepare chokers	.13		.20		**
Hook turn	1.93		2.35		**
Walk out	.57		.69		**
Total hookup time:		3.05		3.81	**
Inhaul		.96		1.08	**
Deck	.39		.49		N.S.
Unhook	.65		.78		**
Total landing time:		1.04		1.27	-
Net cycle time/turn		5.65		6.83	**
Pro-rated road change time/turn		.37		1.21	-
Total productive time/turn		6.02		8.04	-
Pro-rated delay time/turn		1.20		1.28	N.S.
Total time per turn		7.22		9.32	

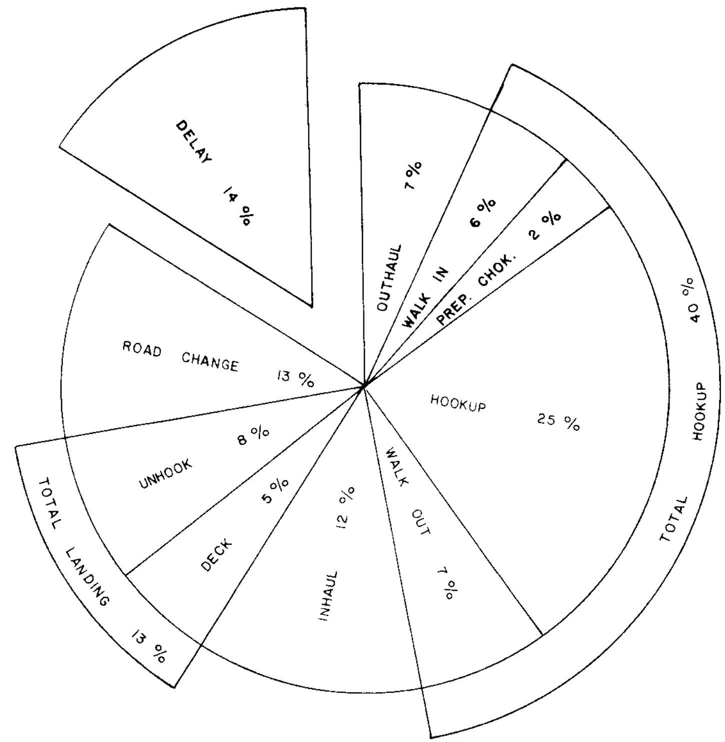
(1) T-Test Results: (analysis of means)
N.S. - no significant difference between means
* - difference was significant at .10 level
** - difference was significant at .05 level
\- - difference not tested

HIGHLEAD



Average 7.22 min. per turn

SLACKLINE



Average 9.32 min. per turn

FIGURE G. Distribution of Element Times.

Prepare Chokers: the three 12-m chokers used during slacklining tangled more often than the two 9-m chokers used during highlead yarding.

Hook: larger turns were hooked during slacklining--3.5 logs per turn versus 2.5 logs per turn.

Inhaul: more time required to yard heavier turns.

Deck: more logs to land.

Unhook: more logs to unhook.

Delays: no significant difference incurred.

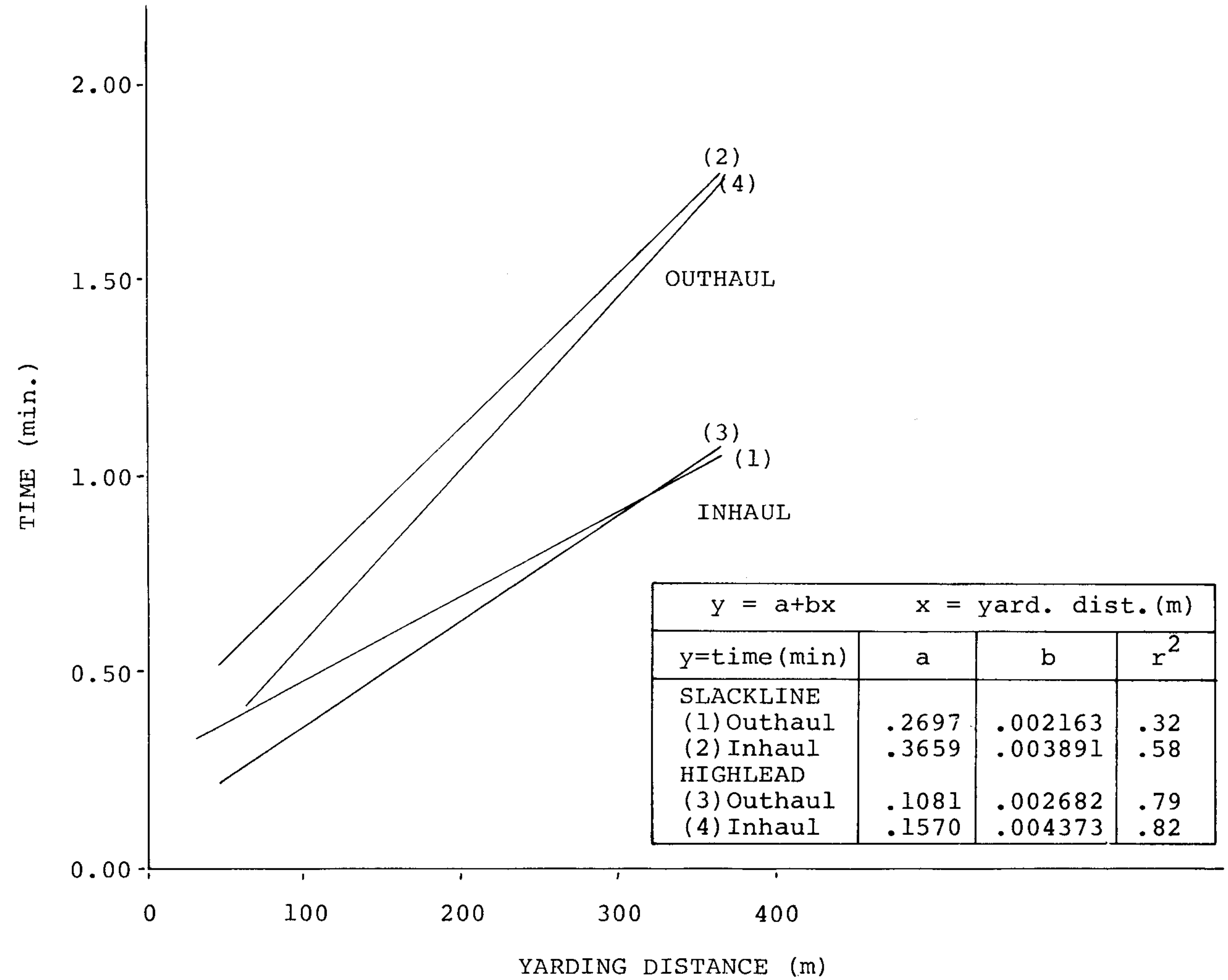
Road Changes: increased time to release and rig the skyline.

Effect of Yarding Distance

Appendix II summarizes data by 30 m (100 ft) yarding distance intervals, up to 330 m for highlead and 300 m for slackline. Only outhaul and inhaul times appeared related to yarding distance. The results of a regression analysis (outhaul and inhaul times versus distance) are shown in Figure H. Generally lower R^2 values for the slackline may reflect variations in time from turn to turn due to positioning the carriage over the turn hook-up point. Average slackline inhaul times were slightly longer than for highlead because the skyline carriage had to be raised (while the turn was slowly yarded in) before full inhaul speed could be reached. Table 4 summarizes the calculated average line speeds.

TABLE 4. Summary of Line Speeds.

	Line Speed (m/s) over 300 m yarding distance	
Rigging Configuration	Outhaul	Inhaul
Slackline	8.7	4.6
Highlead	6.6	3.9



y = a+bx	x = yard. dist. (m)		
y=time (min)	a	b	r^2
SLACKLINE			
(1) Outhaul	.2697	.002163	.32
(2) Inhaul	.3659	.003891	.58
HIGHLEAD			
(3) Outhaul	.1081	.002682	.79
(4) Inhaul	.1570	.004373	.82

FIGURE H. Inhaul and Outhaul Time vs. Yarding Distance.

YARDING ROAD CHANGES

Table 5 summarizes road-change times for the two systems. Pro-rated on a per turn basis, highlead road changes averaged .37 minutes per turn, and slackline 1.21 minutes per turn. Highlead road changes were relatively simple and involved moving the haulback line to one or two new haulback block locations. Slackline road changes were more involved and of two types:

1) moving haulback anchor and using same skyline road,

2) rigging new skyline road
   - utilizing previous haulback block anchor, or
   - establishing new haulback block anchor.

Highlead road changes were probably shorter than for conventional highlead settings because the back rigging crew pre-rigged stumps. Highlead road changes in a previous FERIC study averaged .65 minutes per turn, nearly twice the values found in this study (Sauder, 1978).

TABLE 5. Summary of Road Change Times.

Rigging Configuration	No. of Occurrences	Total Time (min)	Average Time per Occurrence (min)
Highlead:			
Preparing for road change	8	25	3
Road change	10	122	12
Highlead road changes	10	147	15
Skyline:			
Preparing for skyline set-up	3	28	9
Skyline set-up	4	276	69
Skyline road changes	4	304	76
Preparing for haulback road change	11	91	8
Road changes (haulback block move)	8*	175	22
Haulback road changes	8	266	33
Yarder Set-Up	1	175	

*Note: 3 road changes were included in Skyline set-ups.

Delays

Table 6 summarizes delays during yarding production. Although the pro-rated delay time per turn was similar for both highlead and slackline, the delay represented a slightly higher portion of highlead yarding turn time (17%) compared to slackline yarding (14%). In addition, since the slackline turns were larger, highlead delays were greater per volume logged (.40 minutes of delay/m^3 for highlead compared to .31 minutes of delay/m^3 for slackline yarding).

Highlead yarding resulted in twice as many hangups and twice the associated delay time per turn compared to slackline yarding. The occurrence of hangup yarding delays corresponded to an area of unusually high stumps--150 to 275 m from the tower (Figure B).

Delays incurred while waiting for the landing bucker to buck logs in the landing occurred twice as often during slackline yarding. This was probably a result of fewer of the longer logs (18 to 30 m long) breaking during yarding and requiring bucking before loading onto a truck.

Yarding Productivity

Table 7 summarizes the yarding production for the two systems. The slackline averaged 172 pieces per shift (208 m^3) compared to 152 pieces per shift (184 m^3) for highlead. Slackline and highlead yarding times per shift were similar; however, yarding road change time was 2.5 times greater per shift for slackline than for highlead.

During the study, highlead yarding tended to steal logs from the slackline roads. The extra road change time required to accommodate the highlead yarding may have adversely affected slackline productivity.

TABLE 6. Summary of Delays.

	Rigging Configuration					
	Highlead			Slackline		
	No. of Occur-rences	Total Minutes	Minutes/ Occur-rence	No. of Occur-rences	Total Minutes	Minutes/ Occur-rence
Repairs and Service						
Checking yarder for oil leak	1	17	17			
Pick-up faulty radio whistle "bug"				1	10	10
Fuel yarder				2	20	10
Warm-up yarder	6	46	8	10	96	10
Pre-shutdown service	7	23	3	9	35	4
Miscellaneous	3	1				
Total repair and service delays	17	87	5	22	161	7
Operational						
Walk in to start work	2	6	3	-	-	-
Send rigging or fire supplies to crew	6	41	7	6	44	7
Guyline adjustment or pass mainline around	4	62	15	2	37	19
Add or change chokers	16	29	2	11	16	1
Clearing yarding hangups or rigging tangles	46	99	2	24	51	2
Wait for landing bucker	16	15	1	31	33	1
Operator-chaser planning delay	-	-	-	7	6	1
Miscellaneous	12	25	2	27	36	1
Total operational delays	102	277	3	108	223	2
Personnel						
Total crew, operational delays	29	112	4	54	221	4
TOTAL DELAYS	149	476	3	184	605	3
Number of yarded turns	396			473		
Average delay time per turn			1.2			1.3

TABLE 7. Yarding Productivity.

	Rigging Configuration			
	Highlead		Slackline	
		% of Total Time		% of Total Time
Productive time (min)				
Yarding	2,245	78	3,234	73
Yarding road changes	147	5	570	13
Delays (min)				
Mechanical	146	5	204	5
Other delays	330	12	401	9
Total Scheduled Time (min)	2,868	100	4,409	100
Number of shifts observed	6.5		9.5	
Average time/shift (hr)	7.4		7.7	
Number of logs yarded	991		1,632	
Number of logs yarded/shift	152		172	
Average volume/log (m^3)	1.21		1.21	
Average volume/shift (m^3)	184		208	
Number of turns yarded	396		473	
Average no. of turns/shift	61		50	
Average no. of logs/turn	2.5		3.5	
Machine availability	95%		95%	
Machine utilization	83%		86%	

YARDING BREAKAGE

Table 8 shows the number of breaks observed and the estimated volume losses by various breakage types. Yarding breakage was unexpectedly light considering the brittleness of the primarily balsam timber felled one year previous.

Half the breaks occurred close to the log end, and after trimming, resulted in an average 1.8 m length loss. Total yarding volume losses were estimated to be .6% of the slackline yarding volume and 1.4% of the highlead yarding volume. The yarding breakage was calculated to represent

TABLE 8. Summary of Yarding Breakage.

Type of Break	Assumed Volume/Piece			Rigging Configuration			
				Highlead		Slackline	
	Diameter (cm)	Length (m)	Volume (m^3)	No. of Breaks	Total Volume (m^3)	No. of Breaks	Total Volume (m^3)
End of log (1 m + trim loss)	34	1.8	.16	39	6.24	43	6.88
Log broke in half--both halves recovered	29	2.4	.16	31	4.96	31	4.96
Top broken off and not recovered	15	3.0	.06	14	.84	10	.60
Complete log smashed and brought to landing	36	12.0	1.21	3	3.63		
Complete log smashed and not recovered	36	12.0	1.21	1	1.21	1	1.21
TOTALS				88	16.88	85	13.65
Number of yarded pieces				991		1,632	
% - Number of breaks to yarded pieces				9		5	
Volume of yarded pieces (m^3)				1,199		1,975	
% - Volume of breakage loss to total yarded volume				1.4		.6	

$0.57/m^3 of highlead yarded wood and $0.31/m^3 of slacklined wood (based on an average value of $48/m^3 for sawlogs and $26/m^3 for pulp wood).

Figure I illustrates the effect of yarding distance on the incidence of yarding breakage for the two systems. Up to 90 m the number of logs broken, as a percentage of logs yarded for the distance class, was low and similar for highlead and slackline. When yarding from 90 to 275 m, breakage was considerably higher for highlead (greater lift provided by slacklining was expected to reduce breakage). Yarding breakage was highest for both systems at the setting perimeter (14% when highlead yarding between 300 and 330 m and 11% when slackline yarding between 275 and 300 m).

The setting volume was estimated to be 608 m^3/hectare. Average yarding breakage (using the volume of breakage loss percentage calculated in Table 8) would be 9 m^3/hectare for highlead and 4 m^3/hectare for slackline.

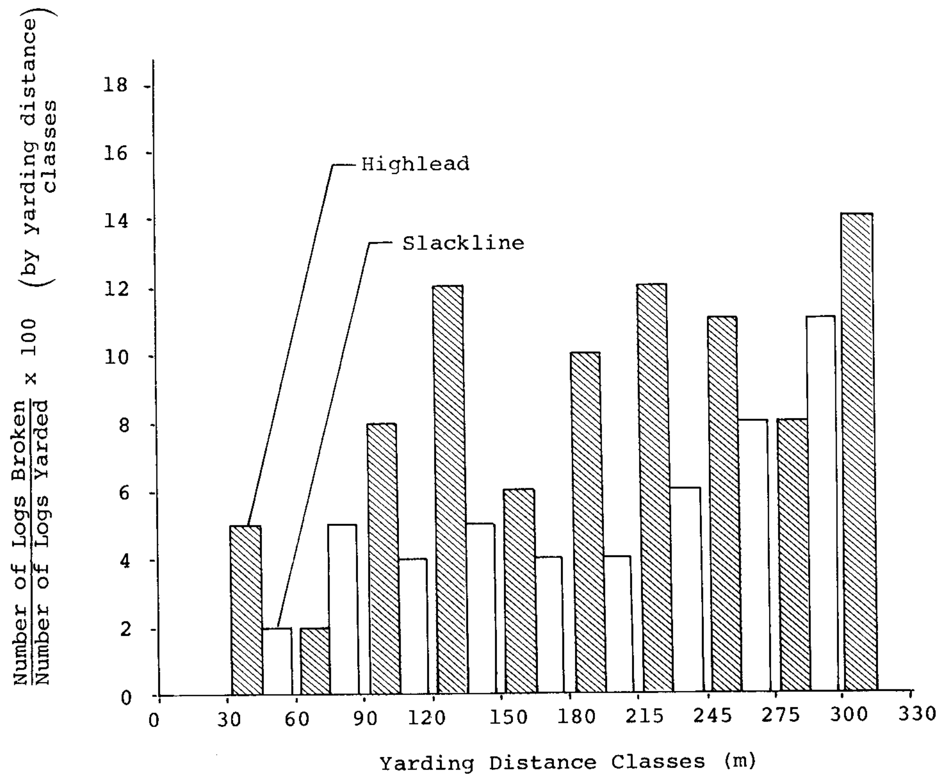


FIGURE I. Effect of Yarding Distance on Yarding Breakage.

Escaped Logs

An average of 15% of the highlead yarded logs and 6% of the slacklined logs slipped out of the chokers on turn breakout or during yarding as chokers slackened. These escaped logs were re-choked later and eventually brought to the landing.

Figure J illustrates the effect of yarding distance on the number of escaped logs. Beyond 150 m, highlead log losses were much more frequent than for slackline. Slackline log escapement gradually increased and levelled off at 9% when yarding from 215 to 300 m yarding distances, whereas for highlead, log escapement increased to 38% of the yarded logs from yarding distances of 245 to 275 m. The variation is probably a result of steadier tension being applied to the chokers and fewer hangups (Table 6) during slacklining compared to highleading.

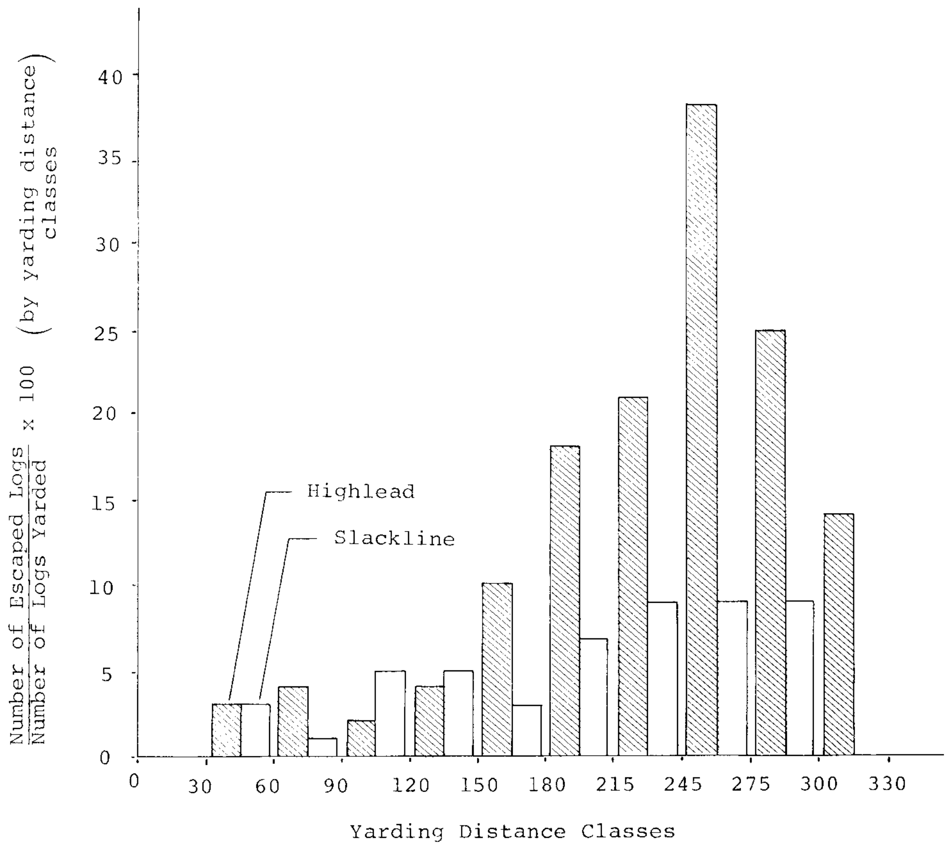


FIGURE J. Effect of Yarding Distance on Escaping Logs.

Net Turn Size

Table 9 summarizes the size of turns yarded during the study by the various number of chokers used. Slackline yarding produced an average of 3.5 logs per turn compared to 2.5 logs per turn for highlead yarding. The number of logs yarded are net, on arrival at the landing, and exclude escaped logs.

TABLE 9. Summary of Net Turn Sizes.

Types of Chokers Used		Rigging Configuration					
		Highlead			Slackline		
Number	Length (m)	No. of Turns	No. of Logs	Logs/ Turn	No. of Turns	No. of Logs	Logs/ Turn
3	9	29	93	3.2	66	279	4.2
3	12	43	115	2.7	228	904	4.0
2	9	208	481	2.3	82	194	2.4
2	12	17	34	2.0	97	255	2.6
2 1	9 10 }	99	268	2.7			
TOTALS		396	991		473	1,632	
AVERAGE				2.5			3.5

YARDING COST COMPARISON

Table 10 summarizes the costs per hour and per m^3 of yarding with the same slackline yarder on the same setting, rigged for highlead and for slackline. It is assumed that the carriage and extra rigging required for slacklining remain with the yarder even though not used in highleading. The crew size was 8 men for highlead and 9 men for slackline yarding. Production rates used are those derived in Table 7.

The yarding costs favour slacklining by $0.29/$m^3$, a minor difference. The costs would have varied more if the highlead road change times had not been artificially reduced by the slackline road changes during the study and the reduced yarding breakage incurred when using the slackline system had been included.

Highlead yarding does not require a backrigging crew. If alternate work could be found for these two men, the highlead operating cost would have been $218 per hour. Yarding production would probably decrease as a result of longer road change times.

Figure K shows the result of a sensitivity analysis comparing yarding cost ($/hr) to production ($m^3$/hr). The two top curves represent the estimated yarding cost based on the calculated study operating costs (Table 10). The lower curve (Highlead Yarding - $218/hr) represents the case when highlead yarding with the Madill 046 yarder and having no back rigging crew. If production was assumed to be reduced by one turn (3.03 m^3) per hour due to the longer time for road changes, an estimated yarding cost of $10 per hour would result.

Figure K also shows how much production must be obtained to maintain a specific yarding cost. In order to maintain a yarding cost of $9.66/$m^3$ (slackline yarding with a full crew), 25.7 m^3 (21 logs) per hour would have to be highlead yarded with a full-sized crew, or 23.4 m^3 (19 logs) per hour highlead yarded with a reduced (no backrigging) crew.

TABLE 10. Estimated Yarding Cost Summary: Highlead and Slackline.[1]

	Rigging Configuration	
	Highlead	Slackline
Madill 046 yarder, cost (1981)	\$455,000	\$455,000
Salvage value (20%)	91,000	91,000
Depreciation value	\$364,000	\$364,000
Depreciation period (years)	8	8
Hours worked per year	1,600	1,600
Interest rate } % of average	15	15
Taxes, insurance, etc. } annual investment	5	5
Ownership cost (\$/hour)	65.41	65.41
Repair and maintenance cost (estimated at 50% of ownership cost)	32.70	32.70
Fuel cost (est.)	9.50	8.75
Oil and lube cost (est.)	.70	.70
Line cost	8.33	8.33
Rigging cost	3.13	3.13
Crew wage[2]	92.58	103.10
Fringe benefits (at 30% of crew wage)	27.77	30.93
Operating cost[3] (\$/hour)	240.12	253.05
Average production per hour (m^3)	24.86	27.01
Average cost of yarded wood (\$/m^3)	9.66	9.37

[1]Costs do not include travel costs, loading supervision, general overhead, etc.

[2]Crew positions and wage rates:

yarder operator	11.80/hr
landing bucker	12.56
landing man	11.20
hook and rig	12.94
back rigger	11.60
back rigging assistant	10.52
rigging slinger	11.44
chokermen (highlead--1; slackline--2)	10.52
	92.58

[3]If alternative work could be found for the back rigger and assistant that are not required during highlead, the estimated operating cost would be \$218 per hour.

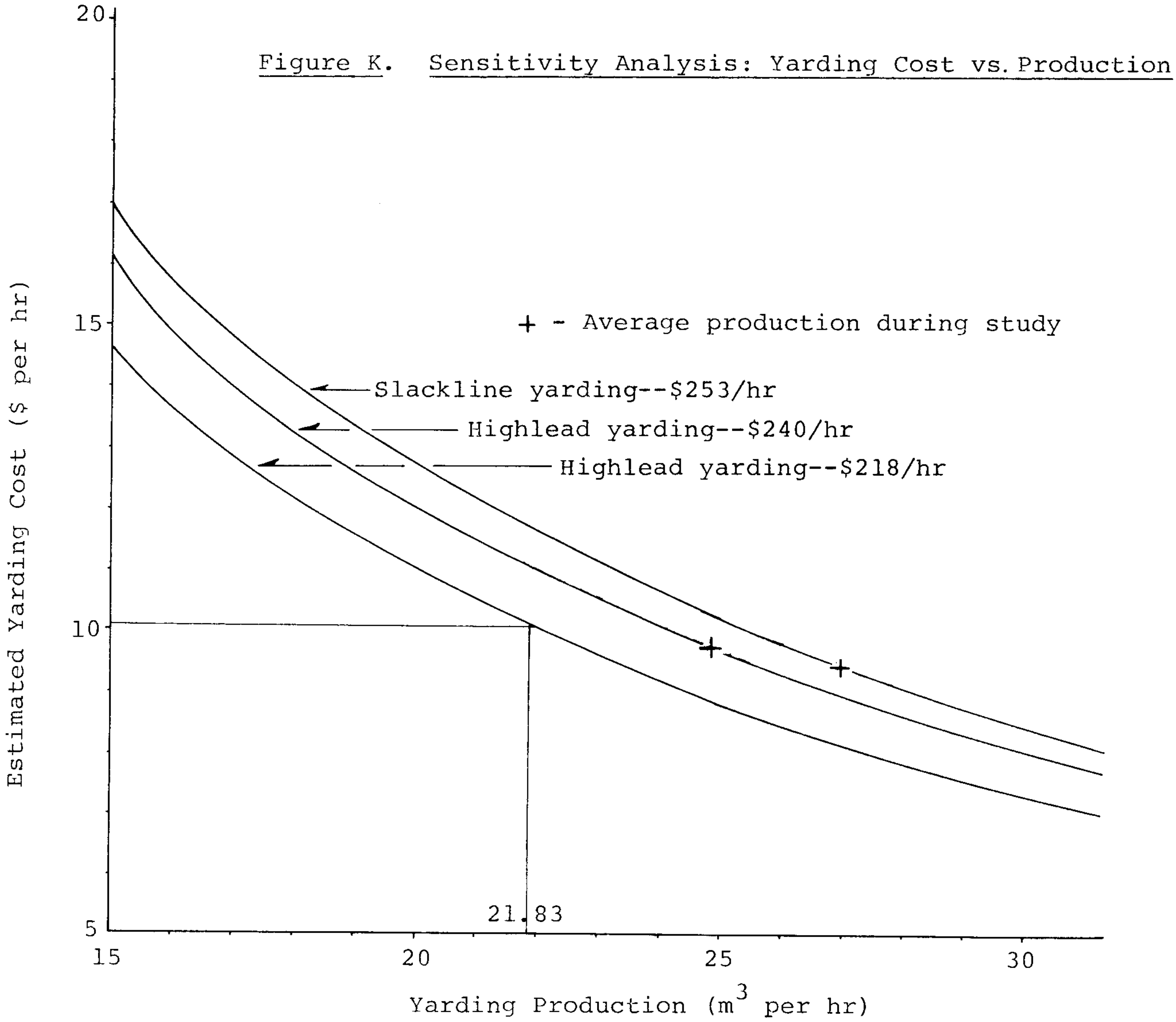


FIGURE K. Sensitivity Analysis: Yarding Cost vs. Production.

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1. Mifflin, R.W. 1980. Computer Assisted Yarding Cost Analysis. Pacific Northwest Forest and Range Experimental Station, General Technical Report PNW-108.

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APPENDIX I

DESCRIPTION OF TIMING ELEMENTS

YARDING

(1) Outhaul--the time required to send the rigging from the yarder to the rigging crew.

(2) Walk-In--the time the rigging crew took to walk from their safe observation spot to the butt rigging.

(3) Preparing Chokers--the time required by the chokermen to untangle the chokers.

(4) Hook-Up--the time required for the rigging crew to set the chokers on the logs selected.

(5) Walk-Out--the time the rigging crew took to walk from where the turn was set, to a safe observation spot.

(6) Inhaul--the time required to bring the turn to the edge of the landing.

(7) Deck--the time required to bring the logs safely to rest on the landing.

(8) Unhook--the time the chaser spent unhooking the chokers from the logs.

ROAD CHANGES

(1) Preparation for highlead road change--the time required to send supplies to the tailhold rigging crew, who were preparing for the next highlead road.

(2) Highlead road change--the time required to complete a highlead road change.

(3) Preparation for skyline change--the time required to send supplies to the tailhold rigging crew, who were preparing the next skyline anchor.

(4) Skyline road change--the time required to set-up the skyline in a new location.

(5) Preparation for slackline haulback road change--the time required to send supplies to the tailhold rigging crew, who were preparing for the next slackline haulback road change.

(6) Slackline haulback road change--the time required to change a slackline haulback road (excluding the skyline).

APPENDIX II

Summary of Detailed Timing by Yarding Intervals

APPENDIX II. SUMMARY OF DETAILED TIMING BY YARDING INTERVALS.

	Yarding Distance Interval (m)	No. of Turns	Average No. Of Logs/ Turn	Time Per Element (minutes)										
				Out-haul	Walk In	Hook Time: Prepare Chokers	Hook Time: Hook Up	Walk Out	In-Haul	Deck	Un-Hook	Net Cycle	Total Delay	Turn Time
HIGHLEAD YARDING	0 - 30	3	3.3	.18	.65	.00	.97	.43	.31	.29	.61	3.44	4.65	8.09
	30 - 60	23	2.8	.26	.35	.11	1.98	.44	.43	.38	.68	4.63	4.40	9.03
	60 - 90	28	2.9	.38	.38	.04	1.95	.62	.52	.36	.59	4.84	.77	5.61
	90 - 120	38	2.6	.41	.46	.16	1.91	.56	.66	.38	.61	5.16	1.86	7.02
	120 - 150	31	2.7	.51	.40	.13	1.93	.56	.74	.43	.64	5.34	1.30	5.64
	150 - 180	55	2.6	.51	.41	.07	1.76	.53	.86	.34	.57	5.05	.60	5.65
	180 - 215	60	2.3	.60	.36	.10	1.94	.56	.94	.40	.61	5.52	.53	6.05
	215 - 245	71	2.4	.66	.57	.21	2.08	.75	1.09	.42	.77	6.54	1.02	7.56
	245 - 275	45	2.2	.80	.43	.22	2.18	.54	1.34	.41	.68	6.60	1.05	7.65
	275 - 300	26	2.5	.97	.35	.03	1.82	.46	1.54	.38	.67	6.23	1.19	7.42
	300 - 330	16	2.2	1.12	.31	.04	1.44	.49	1.68	.39	.69	6.17	.81	6.98
SLACKLINE YARDING	0 - 30	3	2.3	.22	.33	.00	1.14	.33	.37	.49	.64	3.52	8.02	11.54
	30 - 60	18	3.3	.39	.28	.07	2.74	.55	.52	.55	.66	5.77	4.95	10.72
	60 - 90	31	3.3	.48	.46	.08	1.78	.51	.70	.48	.66	5.15	1.99	7.14
	90 - 120	46	3.7	.47	.63	.26	2.08	.74	.73	.48	.74	6.13	.93	7.06
	120 - 150	41	4.1	.57	.55	.27	2.58	.70	.93	.46	.90	6.96	.75	7.71
	150 - 180	68	3.8	.62	.47	.16	2.43	.73	1.05	.51	.95	6.92	1.48	8.40
	180 - 215	76	3.5	.67	.58	.29	2.39	.67	1.10	.48	.75	6.92	1.04	7.96
	215 - 245	95	3.1	.80	.61	.21	2.37	.66	1.32	.52	.74	7.23	1.10	8.33
	245 - 275	75	3.1	.80	.69	.19	2.42	.80	1.29	.47	.71	7.38	.94	8.32
	275 - 300	20	3.3	.94	.58	.13	2.33	.69	1.57	.48	1.05	7.78	.11	7.89