Advantage

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Contents

Coarse woody debris retention during harvesting of coastal old-growth forests

Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied the feasibility of applying training strategies to bucking, and marking following falling but prior to yarding, to increase the amount of coarse woody debris retained in an old-growth stand. FERIC also assessed whether this method was an economically feasible way to reduce delivery of non-merchantable wood to log sortyards and therefore reduce the costs associated with yarding, loading, trucking, and disposing of non-merchantable wood. FERIC's study was part of a larger project initiated by the B.C. Ministry of Forests and Weyerhaeuser Company Limited on coarse woody debris retention.

Keywords

Coarse woody debris, Rotten wood, Biodiversity, Bucking quality control, Debris disposal.

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Introduction

Maintaining coarse woody debris on site during forest harvesting is generally recognized as an important component of ecosystem management (B.C. Ministry of Forests 2000, Dovetail Consulting Inc. 1999; Hopwood 1991; Maser et al. 1984; Maser and Trappe 1984). Under current harvesting practices, some non-merchantable logs are yarded to roadside. Reasons for this include poor visibility of the merchantability class of the log; not wanting the operation to be penalized for leaving merchantable logs on the setting; and inadequate training and understanding of the importance of coarse woody debris. In addition, some of the non-merchantable material is loaded and trucked to the dryland sortyard, and sorted out and disposed of there. Approximately 0.5% of sortyard throughput volume is estimated to be round wood greater than 15 cm requiring disposal (Forrester 1996).[1]

One method of increasing the amount of coarse woody debris on site may be from improved bucking and marking strategies following falling. For example, because of high hourly yarding costs in helicopter yarding operations, fallers are trained to make bucking decisions to maximize value. Marking after bucking to denote merchantability is common in coastal B.C. helicopter operations to ensure only merchantable logs are yarded.

FERIC studied the feasibility of applying training strategies to bucking, and marking following falling, for loader forwarding[2] and grapple yarding operations. The intent of the bucking training and marking activities was to increase the amount and distribution of coarse woody debris retained in the post-harvest block, and to avoid the costs associated with yarding, loading, trucking, and disposing of non-merchantable material. This study was part of a B.C. Ministry of Forests (Davis et al. 2000) and Weyerhaeuser Company

[1] Dryland sortyard residues are estimated to be 5–10% of the yard's throughput volume. This material is composed of round wood, slabs, branches, bark, rocks, and fines, of which 5% by weight is round wood >15 cm.

[2] Loader forwarding is known as "hoe-chucking" in coastal B.C.

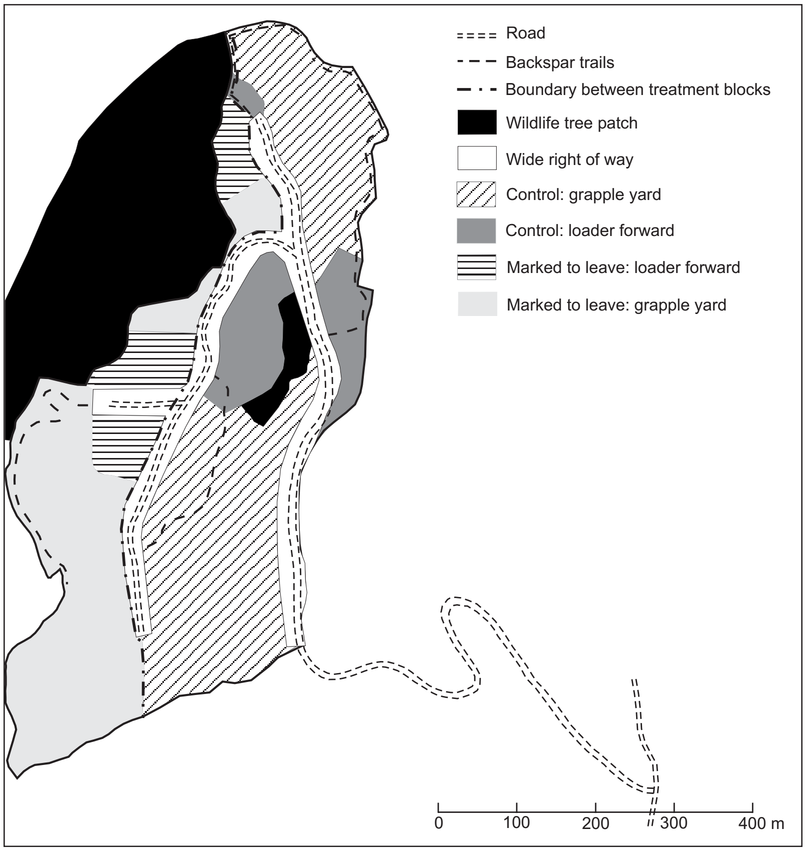
Limited project investigating pre-harvest down coarse woody debris, potential coarse woody debris in standing timber (net factor call grading[3]), and post harvest coarse woody debris levels. This report describes the harvesting phases and presents comparative costs.

Objectives

The objectives of the FERIC component of this project were to:

- Monitor and compare the logistics of conventional yarding with yarding where non-merchantable wood is marked.
- Estimate the costs of falling, yarding, loading, transporting, and disposing of non-merchantable logs.
- Determine if marking of non-merchantable logs after falling but prior to yarding is an effective and economically feasible method to reduce delivery of non-merchantable wood to log sortyards.[4]

Figure 1. Layout of the study site.



Site description

The study site was located on the east coast of Vancouver Island in Weyerhaeuser's North Island Timberlands Kelsey Bay Operation, in the Coastal Western Hemlock (CWH) biogeoclimatic zone. The terrain ranged from relatively flat to greater than 50% slope, and the stand was old-growth forest that was comprised of 48% western hemlock, 49% true fir, and 3% yellow cedar. The study site was divided into two blocks with similar terrain and net timber volumes. The harvesting plan is shown in Figure 1 and Table 1.

A detailed cruise, decay assessment, and coarse woody debris assessment were conducted to characterize the stand (Figure 2). One block was harvested conventionally (control block), while the second was harvested with additional in-woods bucking training and with the marking of non-merchantable logs prior to yarding (marked-to-leave treatment block).

Harvesting and equipment description

The harvesting techniques and equipment used are common in coastal B.C. operations. All falling was motor-manual (Figure 3). Three harvesting systems were used:

- A wide right-of-way was yarded using a hydraulic log loader and a line loader.

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3 Net factor call grading is a process used during timber cruising to assess timber quality and tree volume.

4 The BCMOF study measured the amount and type of coarse woody debris in the post-harvest blocks and at roadside to determine the effectiveness of the training and bucking on coarse woody debris retention.

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Table 1. Harvesting summary		
Harvest method	Area (h) [a]	Volume harvested (m^3)
Wide right-of-way (loader yarding from road)	3.4	1 272
Loader forward	3.9	3 341
Grapple yard	13.6	8 831
Subtotal	20.9	13 444
Setting right-of-way	2.7	3 243
Wildlife tree patch and in-block reserve	8.9	n/a
Total block	32.5	16 687

[a] Areas are estimated from post-harvest maps.

- Flatter areas were yarded by loader forwarding to roadside (Figure 4) with the same hydraulic log loader used to load the trucks.
- The remainder of the area was yarded with a three-drum grapple swing-yarder (Figure 5) and a mobile backspar.

A tridem truck/tridem pole trailer seven-axle configuration (Figure 6) hauled the logs to a central dryland sortyard via off-highway roads.

Study methods

FERIC compared the additional costs of training and marking to the reduced cost realized by handling less non-merchantable material in the harvesting, transport, and disposal phases. Costs and productivities for each phase were calculated for the marked-to-leave treatment and control blocks, and compared on a gross volume basis.

Costs were calculated on a cubic metre basis with the hourly costs derived from FERIC's costing model in Appendix I; the machine and crew hours from company time card records; wage rates from Appendix II; and the gross volumes from company dryland sortyard scale records. A cost of $50/day was used for falling equipment costs. Because of differences between blocks, harvested volumes, and harvesting methods, costs were compared for equal net volumes with actual productivities and sortyard cull rates.

Figure 2. Pre-harvest site assessment.

Figure 3. Motor-manual falling.

Figure 4. Loader forwarding to roadside.

Figure 5. Three-drum grapple yarder in treatment block.

Figure 6. Seven-axle logging truck hauling an off-highway load.

Figure 7. Training of fallers.

Figure 8. Marking non-merchantable logs.

The logistics of yarding and loading were documented with detailed monitoring on a cycle and truckload basis. Trucking productivities were calculated with actual road lengths, tridem truck/tridem pole trailer specifications for off-highway loading, and a FERIC costing model (Blair 1999) based on the assumptions shown in Appendix III.

To determine the sensitivity of overall costs to hauling distance, an analysis of estimated hauling cost was done for two and three times the actual length of 25 km. As well, the off-highway truck loading used in the study was compared to highway-sized loads.

The costs to dispose of the non-merchantable volume using various methods were calculated to determine the sensitivity of the overall costs to disposal methods. The disposal methods used in this study were open burning at the dryland sortyard (Sinclair 1981), using a “smokeless” burner (Forrester 1999), and processing into hog fuel (Forrester 1996). The processing costs assume the hog fuel produced has no net value at the end-user’s facilities.[5]

The FERIC study does not compare coarse woody debris orientation or pre- and post-harvest volumes. These attributes are addressed in a B.C. Ministry of Forests study (Davis et al. 2000; Davis and Linnell Nemec 2003). A descriptive video documenting the FERIC study was produced.[6]

Results and discussion

Training and marking

The fallers were trained in improved bucking techniques by a consultant experienced in training and marking for helicopter logging operations (Figures 7 and 8). The training appeared to be successful because the fallers were interested in upgrading their skills. Because the logs were often stacked several deep, only the logs located in the upper layer could be marked by the consultant’s crew because of visibility and safety concerns. However, the markers estimated that the marked logs represented about 70% of the non-merchantable logs. Cost estimates for

[5] Additional background information can be found in Appendix IV.

[6] Retention of coarse woody debris – pilot study (March 2002). 8 min. Video produced by FERIC, Vancouver, B.C. Available upon request.

the training and marking are shown in Table 2. Re-marking was required because most of the marked section of the block was yarded late in the season, and snow and fog compromised the visibility of the marks. To improve visibility for both the yarding engineer and spotter, both sides of each log were marked the second time.

Table 2. Training and marking costs

Activity	Work days	Cost ($)	Unit cost ($/m^3)
Bucking training	10	2 810	0.43 [a]
Marking to leave	6	1 686	0.26
Re-marking	4	1 124	0.17
Total	20	5 620	0.86

[a] Costs are based on I.W.A. wage rates from Appendix II and the volume of 6537 m^3 delivered to the dryland sortyard from the grapple yarded, excavator forwarded, helicopter yarded, and wide right-of-way areas in the marked-to-leave block. The volume does not include the post-study salvage of pulp and low grade logs from roadside.

Falling

Training during the trial period and the additional bucking required were anticipated to decrease the faller productivity on the treatment block. In fact, the highest productivity was found in the treatment area, probably because of the crew used there. Therefore, the average falling cost for the whole study site was used in each block comparison to avoid crew bias.

Yarding

Although the marked-to-leave treatment and control blocks were similar in area, piece size, and yarding chance, the total volumes and proportions yarded by the three harvesting systems were different. Therefore, comparisons were based on the calculated productivities and cull rates applied to a 7 000 net m^3 block in the following proportions: 65% grappling yarding, 10% wide right-of-way with a line loader, and 25% loader forwarded with a hydraulic log loader.

Loader forwarding

Marking did not alter normal operations in the loader-forwarded area. The loader-forwarder operator was able to routinely check each log for merchantability by turning each log or by bringing the log close to the cab. As well, he moved every log to clear the path for the forwarder travelling within the block. The practice of discarding non-merchantable logs resulted in piles of this material in both the marked and control blocks. Some of the non-merchantable logs were used to build a corduroy-type trail for the forwarder. Much of the decayed non-merchantable material was broken during the handling process. The operator suggested the piled material could be dispersed during forwarding with a little extra time if guidelines were provided.

Grapple yarding

The yarding cycles for the marked-to-leave treatment and control blocks are compared in Table 3. The times spent for each element were similar for both blocks with the exception of hookup and deck, which were greater for the marked block. The increased hookup time resulted from the deteriorating weather and poor visibility as the study moved into the fall season. Decking time was higher in the marked block because landings were generally smaller and steeper, and decking was more difficult. Although different operators yarded the two areas, their yarding strategies did not appear to affect their overall productivities.

Some of the marked logs were moved during yarding to clear the yarding road. Even with the re-marking, the yarder operators and the spotter often could not see the blue paint on the logs, especially as the weather conditions worsened. Some high visibility pink paint was also used, and this appeared to increase the visibility of the marks.

One of the yarding operators suggested yarding the non-merchantable logs back into the block as an alternative to marking. The logs could be returned to the yarding road during the outhaul portion of the cycle. This strategy would increase the total cycle time of the affected yarding cycles by about 30% for the additional hookup and reduced

Table 3. Yarder, detailed-timing summary

Cycle element (average min/cycle)	Control block	Marked block
Outhaul	0.34	0.33
Hookup	0.48	0.77
Inhaul	0.38	0.39
Deck	0.14	0.41
Abandon non-merchantable wood	0.02	0.06
Hang-ups	0.01	0.04
Move yarder	0.03	0.04
Move backspar	0.19	0.19
Delays (<10 min)	0.22	0.21
Total cycle	1.81	2.44
Yarding distance (average m)	94	102
Logs/cycle (average no.)	1.2	1.1
Sample size (no. of cycles)	560	297

outhaul speed. If 10% of the yarding cycles backhauled non-merchantable logs, the overall effect would be an increase of about 3% in the average yarding cycle time. However, for this scenario to work, non-merchantable logs would have to be identified at the landing almost as soon as they arrive. As well, deflection would have to be sufficient to allow the reject log to be dropped on or near the yarding road, without affecting subsequent yarding cycles.

A more viable scenario would be to identify non-merchantable logs at roadside after the yarding road is yarded but before the yarder moves to the next yarding road. To back yard 10% of the logs from the roadside deck would increase yarding time by 10%, assuming the back yarding cycles take the same time as productive cycles, the logs could be identified in the deck in the time it takes for the hooktender to check the yarding road for merchantable logs, and the average number of logs per cycle stays the same.

Handling non-merchantable logs twice will likely lead to more breakage which will render the logs less useful from a long-term biodiversity standpoint.[7]

Loading and bucking

The time distribution for the loader was derived from detailed timing (Table 4). The loader sorted logs, removed any non-merchantable logs, spread logs for the bucker to remanufacture or upgrade, and loaded trucks. In addition, the loader also forwarded logs to roadside on the more gentle terrain. The primary difference in loading time between the two blocks was in the sorting function. Different loader operators were used for the two blocks; the marked block was loaded in two different years; and several different buckers were observed. However, reduced sorting and bucking would be expected to occur if woods bucking was improved.

Table 4. Loader, detailed-timing summary

	Control block		Marked block	
	min/load	% of total	min/load	% of total
Truck loading	32.4	55.6	29.2	67.4
Sorting	14.8	25.4	1.6	3.7
Bucking [a]	4.9	8.4	7.2	16.6
Idle, wait truck	6.2	10.6	5.3	12.3
Total	58.3	100.0	43.3	100.0

[a] Some bucking takes place during the other loader activities. The bucking time shown in the table is the bucking time that interrupts other loader functions.

[7] The length and diameter of coarse woody debris are important from a biodiversity standpoint. Larger coarse woody debris will have the greatest ecological impact and will persist for the longest period of time.

Trucking

Trucking simulation results are shown in Table 5 and were based on the assumptions described in Appendix III. The gross combination weights (GCW) modelled are a recommended maximum stable load weight for the tridem truck/tridem pole trailer configuration on off-highway routes.[8] The costs are dependent on both load and haul distance. For example, doubling the haul distance would increase the cost by 1.5 to 2 times depending on the shift length. If the destination were the nearest processing facility via a highway route, payload would decrease compared to off-highway and the costs would increase because haul distance would be greater.

Log sorting and disposal at the dryland sortyard

The scaled, non-merchantable waste rate of less than one percent is consistent with previous studies. Only a small difference in the volume of non-merchantable material was found between the marked-to-leave treatment and control blocks but the reason is not clear. The company program for quality control was active during roadside bucking for both blocks. Also, post-yarding roadside salvage took place for both blocks and it is suspected that any logs of marginal merchantability were left for this later phase. An additional 4 090 pieces and 1 411 m^3 were removed from both blocks during roadside salvage of primarily pulp logs, after the end of the project.

Although the volumes were similar between the two blocks, the type and characteristics of the non-merchantable material for disposal were different. The company scaling classifies the waste into four categories: culls (non-merchantable logs), trim ends and manufacturing loss (trim to create mill-ready logs), and sortyard use (low grade logs used as part of the sortyard infrastructure). The waste from the marked-to-leave treatment block contained fewer larger logs—8 cull logs compared to 33 in the control block. The control block also had 75% more volume in its manufacturing waste compared to the treatment block, illustrating the result of improved in-woods bucking quality. There were few differences in the volumes in the other categories.

Overall cost and value comparison

Comparative costs were calculated for the two blocks using equal net volumes and equal proportions of the three extraction

[8] Séamus Parker, FERIC, personal communication, December 2002.

Table 5. Trucking costs [a]

	Off-highway haul	Highway haul
Gross combination weight (GCW) (kg)	68 700	54 500
Ownership and operating costs ($/h)	128.19	125.32
Unit cost at 25 km one-way haul ($/m³)		
3 loads/shift	6.15	8.40
Unit cost at 50 km one-way haul ($/m³)		
2 loads/shift	9.23	12.60
Unit cost at 75 km one-way haul ($/m³)		
1 load/shift	18.46	25.20
Unit cost at 100 km one-way haul ($/m³)		
1 load/shift [b]	18.46	25.20

[a] From the Foothills Model Forest log transportation cost model.

[b] The cost for 75 and 100 km remains the same because the program costs are based on the complete number of trips a truck can make within the chosen shift length. The truck can complete either one 75 km trip or one 100 km trip within the 8-h shift.

methods (wide right-of-way, loader forward, and grapple yard). The cost differences, by phase, are shown in Table 6. Gross volumes were calculated using the measured cull rate.[9] The main increase in costs for the treatment block resulted from training and marking, and the main cost savings came from loading.

A comparison was done to test the sensitivity of the total harvest cost to different trucking and disposal scenarios, and to determine the required reduction in cull rate at the dryland sortyard that would justify the additional costs of marking and training. Figure 9 expresses the productivities in Table 6 graphically. This comparison includes the assumptions that the improved loading efficiency due to processing, better in-woods bucking, and fewer non-merchantable logs are related to the treatment, and that the loader is fully utilized loading trucks. With any cull rate, a cost savings from training and marking would result, primarily because less sorting and manufacturing would be required at roadside.

Figure 10 illustrates the same comparison but with equal loader productivities between treatments. On many coastal operations, the availability of trucks is the factor that limits loader time and truck productivity.[10] In this scenario, a 2.25 to 3.25% reduction in cull rate at the dryland sortyard would be required to offset the training and marking costs.

Figure 11 also assumes equal loader productivities but without the re-marking and training, i.e., using the marking costs

[9] The cull rate of 0.88% for the control block and 0.76% for the treatment block was the volume of logs rejected and disposed of at the sortyard as a percentage of the gross volume delivered to the sortyard.

[10] If a truck is not available, many loader operators will spend additional time on secondary activities such as sorting instead of sitting idle. Operations will change from loader limited with a queue of trucks to truck limited with the loader waiting for trucks during the same shift. Experienced loader operators will sort and process loads during truck limited periods to allow quicker loading during loader limited times.

Table 6. Cost comparison by harvesting phase

Harvesting phase	Gross volume: control block (m^3)	Gross volume: marked block (m^3)	Net volume/ block (m^3)	Cost: control block ($/$m^3$) [a]	Cost: marked block ($/$m^3$) [a]	Cost difference: Control minus marked ($/$m^3$) [b]
Falling	-	-	7 000	6.15	6.15	0.00 [c]
Faller training, marking, and remarking	-	-	-	0.00	0.86	-0.86
Yarding						
Wide right-of-way	706	705	700	16.94 [d]	16.94	0.02
Loader forward	1 765	1 763	1 750	4.42	4.42	0.01
Grapple yard	4 590	4 584	4 550	17.55	17.55	0.02
Total yarding	7 062 [e]	7 053 [e,f]	7 000	-	-	0.02 [f]
Loading	6 355	6 348	6 300	4.17	3.15	1.03
Trucking	7 062	7 053	7 000	5.64	5.64	0.01
Debris disposal	62	53	-	3.30	3.30	0.00 [g]
Total, all phases	-	-	-	-	-	0.20

[a] Based on gross volume, FERIC costs, and actual productivities.
[b] Based on (control block $/$m^3$ × control block gross volume – marked block $/$m^3$ × marked block gross volume) / net volume.
[c] An overall average cost for both blocks combined was used with the same gross and net volumes.
[d] Includes yarding and loading.
[e] Differences are a result of rounding.
[f] Areas are estimated from post-harvest maps.
[g] Disposal cost per merchantable cubic metre.

only. If training and marking were applied on a broader scale, such as to a whole company division, neither re-marking nor training should be required on every block. A cull rate reduction of 0.5 to 1% would be required to offset the marking cost in this scenario. Training could be incorporated into an existing quality control program with minimal extra cost.

Average log values were compared between blocks based on October 2001 prices. Yellow cedar had three times the average value per cubic metre of the other logs but it was only found in the control block. If this wood is excluded, the average net and gross log values would be equal between the blocks.

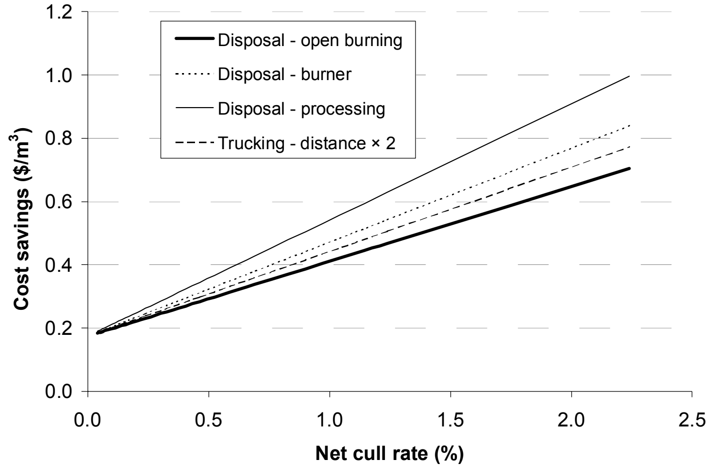

Figure 9. Cost sensitivity, assuming improved loader efficiency for the marked-to-leave treatment.

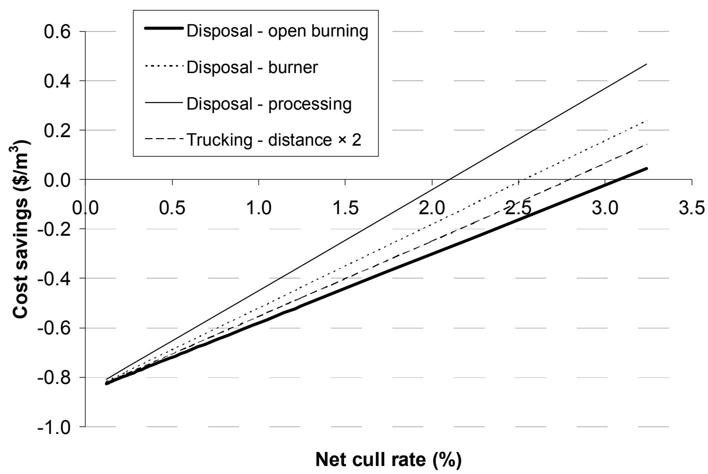

Figure 10. Cost sensitivity, assuming equal loader productivities for the treatments.

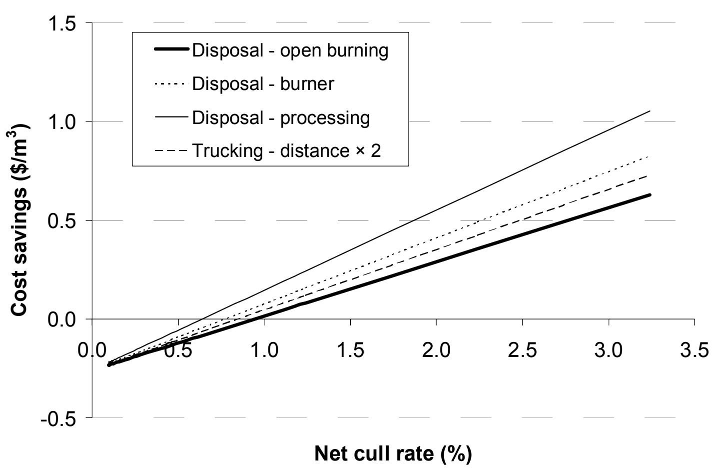

Figure 11. Cost sensitivity, assuming equal loader productivities using marking costs only.

Conclusions

The challenge when managing for coarse woody debris, from a biodiversity standpoint, is to leave enough logs to meet both short- and long-term ecosystem requirements. However, no dollar value is placed on retained coarse woody debris, and the B.C. Ministry of Forests' short term strategy specifies no net economic impact. The harvesting challenge is to yard all economically viable logs. Economic viability varies with current log values, utilization/merchantability standards, yarding chance, and transportation distance. This report examines only logging, transportation, and disposal cost scenarios for a coastal old-growth case study.

Overall, there were no net cost savings from training and marking because the difference in the cull rate of the logs delivered to the sortyard was small when comparing the control and treatment blocks.[11] The production costs of logs are sensitive to cull rate, trucking distance, and dryland sortyard disposal method. In this case study, the cull rate of logs delivered to the dryland sortyard

[11] In addition, the B.C. Ministry of Forests study did not find any significant differences in coarse woody debris retention between the two blocks (Davis and Linnell Nemec 2003).

would need to decrease 0.5 to 1% before the training and marking would show a payback. This is based on the assumptions that the operation is not loader limited and that re-marking of non-merchantable logs is not required.

Additional training of fallers to improve bucking decisions in an old-growth stand did not appear to decrease faller productivity. Training also appeared to have reduced log manufacturing and related waste at the dryland sortyard. If this level of training is not required on every block, there may be economic justification for training, provided the fallers accept the training and it can be incorporated into an existing quality control program.

In some operations, reduced costs in yarding, loading, trucking ,and disposal may achieve payback of marking costs. If the existing cull rate at the sortyard is high, more potential is available to reduce costs through marking and training. The cost of trucking non-merchantable logs becomes higher as distances increase or gross truck/trailer combination weights decrease. The cost of disposing cull logs at the sortyard is also an important factor when determining the economic viability of marking and training alternatives.

If marking in the setting is not viable, back yarding of non-merchantable logs may be an option but this may require training of the yarder operator or chaser. Monitoring would be needed to ensure this strategy is economically feasible.

Implementation

The value of marking and training to an operation depends on current cull levels, the cost of delivering those culls to the sortyard or mill, and the subsequent cost of disposal. The higher the existing transportation and disposal costs, the easier it is to receive a net payback from training and marking. The greatest value would therefore be in old-growth stands with a high cull rate, located far from the sortyard or end user.

Marking of non-merchantable logs prior to harvesting was effective when the marks were readily visible. To apply this technique on a larger scale, more lasting and visible marking needs to be explored. Marks need to be visible from both the yarder operator's and the hooktender's viewpoint. Ideally, all non-merchantable logs should be marked, instead of the estimated 70% in this study. To achieve higher levels of marking, marking by the fallers would need to be explored. Marking is most effective where the falling and yarding crews are interested in minimizing yarding of non-merchantable logs.

Ongoing quality control for roadside bucking was already part of the company's strategy to reduce costs. Training of fallers to leave non-merchantable material was therefore an effective additional strategy because the fallers in this block were interested in improving their quality control. This strategy could be applied on a broader scale, especially within existing quality control programs, if fallers are interested in participating and if logs can be bucked without waste assessment penalties. Waste should not be an issue if the training program has adequate faller acceptance and follow-up.

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Appendix I

Machine costs [a]

	Swing yarder	Backspar	Hydraulic log loader	Loader forwarder	Line loader [b]
Weight (kg)	90 000	-	50 000	50 000	-
Age	new	4 years	new	new	new
OWNERSHIP COSTS					
Total purchase price (P) $	1 350 000 [c]	205 000 [d]	534 000	534 000	1 450 000
Expected life (Y) y	12	10	8	6	12
Expected life (H) h	17 280	14 400	11 520	8 640	17 280
Scheduled hours/year (h)=(H/Y) h	1 440	1 440	1 440	1 440	1 440
Salvage value as % of P (s) %	20	20	20	20	30
Interest rate (Int) %	9	9	9	9	9
Insurance rate (Ins) %	1.5	2	2	2.5	2
Salvage value (S)=((P•s)/100) $	270 000	41 000	106 800	106 800	435 000
Average investment (AVI)=((P+S)/2) $	810 000	123 000	320 400	320 400	942 500
Loss in resale value ((P-S)/H) $/h	62.50	11.39	37.08	49.44	58.74
Interest ((Int•AVI)/h) $/h	50.62	7.69	20.02	20.02	58.91
Insurance ((Ins•AVI)/h) $/h	8.44	1.71	4.45	5.56	13.09
Total ownership costs (OW) $/h	121.56	20.78	61.56	75.03	130.73
OPERATING COSTS					
Wire rope (wc) $	11 000	-	-	-	8 000
Wire rope life (wh) h	1 000	-	-	-	2 000
Fuel consumption (F) L/h	60	5	30	30	40
Fuel (fc) $/L	0.65	0.65	0.65	0.65	0.65
Lube & oil as % of fuel (fp) %	10	10	10	10	10
Track & undercarriage replacement (Tc) $	-	-	32 000	32 000	-
Track & undercarriage life (Th) h	0	0	8 000	5 000	0
Annual operating supplies (Oc) $					
Annual repair & maintenance (Rp) $	90 000	16 400	50 200	67 000	60 000
Shift length (sl) h	8	8	8	8	8
Wire rope (wc/wh) $/h	11.00	-	-	-	4.00
Fuel (F•fc) $/h	39.00	3.25	19.50	19.50	26.00
Lube & oil ((fp/100)•(F•fc)) $/h	3.90	0.33	1.95	1.95	2.60
Track & undercarriage (Tc/Th) $/h	-	-	4.00	6.40	-
Repair & maintenance (Rp/h) $/h	62.50	11.39	34.86	46.53	41.67
Total operating costs (OP) [e] $/SMH	116.40	14.96	60.31	74.38	74.27
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP) [f] $/SMH	237.96	35.75	121.87	149.41	205.00

[a] Differences due to rounding.
[b] Based on a Madill 075 line loader.
[c] The Madill 044 yarder was used in this study but it is no longer manufactured. This is an estimate of the current cost to manufacture this machine.
[d] Backspar cost includes purchase of used excavator ($125 000) and the cost to convert it to a backspar ($80 000).
[e] Costs do not include labour.
[f] These costs are based on the costing assumptions shown and are not the actual costs for the operation studied.

Appendix II

Wage rate and duties

Position	Duties	I.W.A. group number	Rate ($/h, August 2000) [a]	All found rate (rate + 40% fringe benefit loading)
Faller	• Fall trees and buck into preferred log lengths	F&B	38.11 [b]	53.35
Licensed scaler/grader	• Train buckers • Mark non-merchantable logs in trial block	12	25.09	35.13
Loader operator (line and hydraulic)	• Sort logs at roadside • Load merchantable logs on trucks • Spread logs for upgrading by second loader	11	24.40 ½	34.17
Second loader (landing bucker)	• Assists with truck and trailer setup • Timber marks load and issues load slip • Re-bucks loads at roadside and checks for merchantability of marginal logs	8	22.87 ½	32.02
Loader forwarding operator	• Forward logs to roadside in flatter areas and forward logs along a wide right-of-way • Yard wide right-of-way from road	13	25.76 ½	36.07
Grapple yarder operator (yarding engineer)	• Operate grapple yarder • Coordinate rigging, road changes, line repairs	13	25.76 ½	36.07
Hooktender	• Rig for road changes • Move backspar • Spot grapple on logs for grapple yarders operator during poor visibility situation	12	25.09	35.13
Utility man	• Repair lines • Assist in road changes	7	22.58 ½	31.62
Truck driver	• Drive truck and related duties	10	23.95 ½ [c]	33.54

[a] I.W.A. rates are shown and used in the calculations. The ½ shown is 0.5 cent.
[b] Falling and bucking are based on $304.88/day.
[c] Rate includes $0.20/h for three-axle trailer.

Appendix III

Assumptions for trucking model

Road criteria	Speeds loaded/ empty (km/h)	25 km haul, road section lengths (km) (study road)	50 km haul, road section lengths (km) (study road × 2)	75 km haul, road section lengths (km) (study road × 3)
Road section				
Spur road (block access)	10/10	1	2	3
Secondary haul road	20/40	4	8	12
Main haul road	30/50	4	8	12
Mainline (gravel)	55/60	9	18	27
Mainline (paved)	50/60	7	14	21
Total	-	25	50	75

Truck costing	Tractor – off-highway	Trailer – off-highway	Tractor – highway	Trailer – highway
Ownership costs				
Insurance cost (%)	2.3	2.3	2.3	2.3
Registration cost (%)	2.5	2.5	2.5	2.5
Purchase cost ($)	179 000	68 000	179 000	68 000
Salvage value (%)	36	24	36	24
Life-time (years)	4	8	4	8
Interest	9	9	9	9
Operating costs				
Fuel cost ($/L)	0.65	-	0.65	-
Fuel use (L/h)	34	-	34	-
Lube, oil cost (%)	15	-	15	-
Tire cost ($)	480	290	480	290
Tire consumption (tires/year)	28	12	25	11
Operating supplies cost ($/year)	1 300	200	1 170	180
Repair, maintenance cost ($/year)	12 703	7423	11 400	6 700

Other assumptions:
- 30 minutes loading time per load; 30 minutes unloading time per load.
- 10 minutes wrapper check per load; 5 minutes miscellaneous time per load.
- 0% profit allowance; complete trips only, 8-h shift.
- weight volume conversion = 900 kg/m^3.
- off-highway: GCW 68 700 kg, payload 50 000 kg; highway: GCW 54 500 kg, payload 35 800 kg.

Appendix IV

Debris disposal background

Debris disposal

Non-merchantable material may be disposed of using a variety of techniques depending on the location and type of material. In the past, post-harvest broadcast burning of settings was common to reduce fire hazard and brush competition and to prepare the site for regeneration. Currently, roadside debris is treated by piling and burning after the salvage of merchantable material such as cedar blocks. Non-merchantable material at the dryland sortyard results from log grading, handling, and manufacturing. This material is usually landfilled or burned, or hogged and utilized for energy if the yard is close to a manufacturing facility. The costs of debris treatment are related to the disposal location and method.

Roadside disposal

In coastal B.C., salvage contractors remove useable material prior to piling debris at roadside. The remaining material is then typically burned where this method is still allowed or, in some cases, chipped or hogged and blown back into the setting. Piling and burning of roadside piles in the interior of B.C. have been reported to cost \$0.25/harvested m^3, and chipping (hogging) to waste has been reported at \$0.65/harvested m^3 (Hunt 1994). Economic chipping is dependent on chip prices and the amount and quality of material at roadside. Hedin (1991) estimated the market value would have to exceed \$30/solid m^3 and the roadside piles would need to be >70% chip quality logs to financially break even. Smoke production from burning is a concern in some forestry operations.

Dryland sortyard disposal

In most dryland sortyards, woody debris is considered to be more of a nuisance than a resource (MacDonald 2001), especially when the material becomes contaminated with inorganic material. In the past, much of the sortyard debris was landfilled or burned. Sinclair (1981) calculated burning costs to be \$0.11–\$0.22/m^3 of wood sorted or \$2.20–\$4.40/m^3 of material burned at a 5% debris/wood sorted generation rate. Sanitary landfill costs were \$0.14–\$0.24/m^3 of wood sorted for landfills 8.9 and 14.5 km from the sortyard, respectively. Forrester (1996 and 1999) updated these costs in two case studies to \$9.35/m^3 to sort, burn, and landfill in the interior of B.C., and \$14.32–\$18.32/m^3 (of debris basis) to process debris in coastal B.C. Forrester (1991) also calculated costs of landfilling in an engineered landfill, to meet current environmental regulations in urban Alberta, to be \$43.92/m^3 including handling equipment or \$16.95/m^3 for the landfill alone.[12] In the operation studied, the disposal of dryland sortyard residues is a liability because there are no conversion facilities close to the yard to allow economic energy or pulp-chip production. Current energy prices make hog fuel more viable. However, in the past this has only been a short-term phenomena.

[12] Based on a development cost of \$3.5 million for a landfill with a 206 000 m^3 capacity.