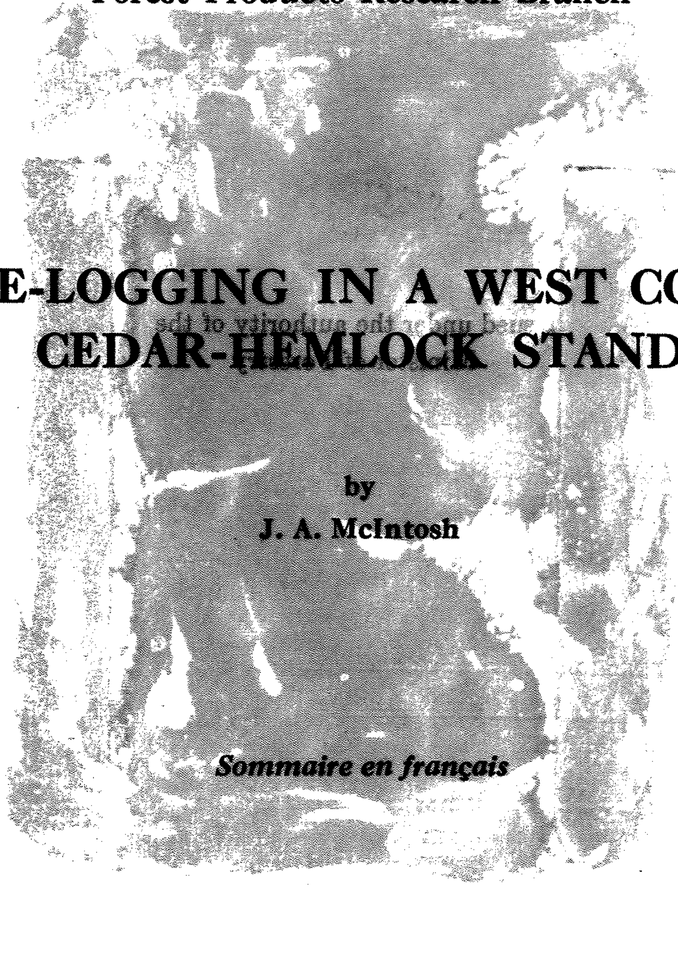
Forest Products Research Branch



PRE-LOGGING IN A WEST COAST CEDAR-HEMLOCK STAND

by

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Sommaire en français

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SUMMARY

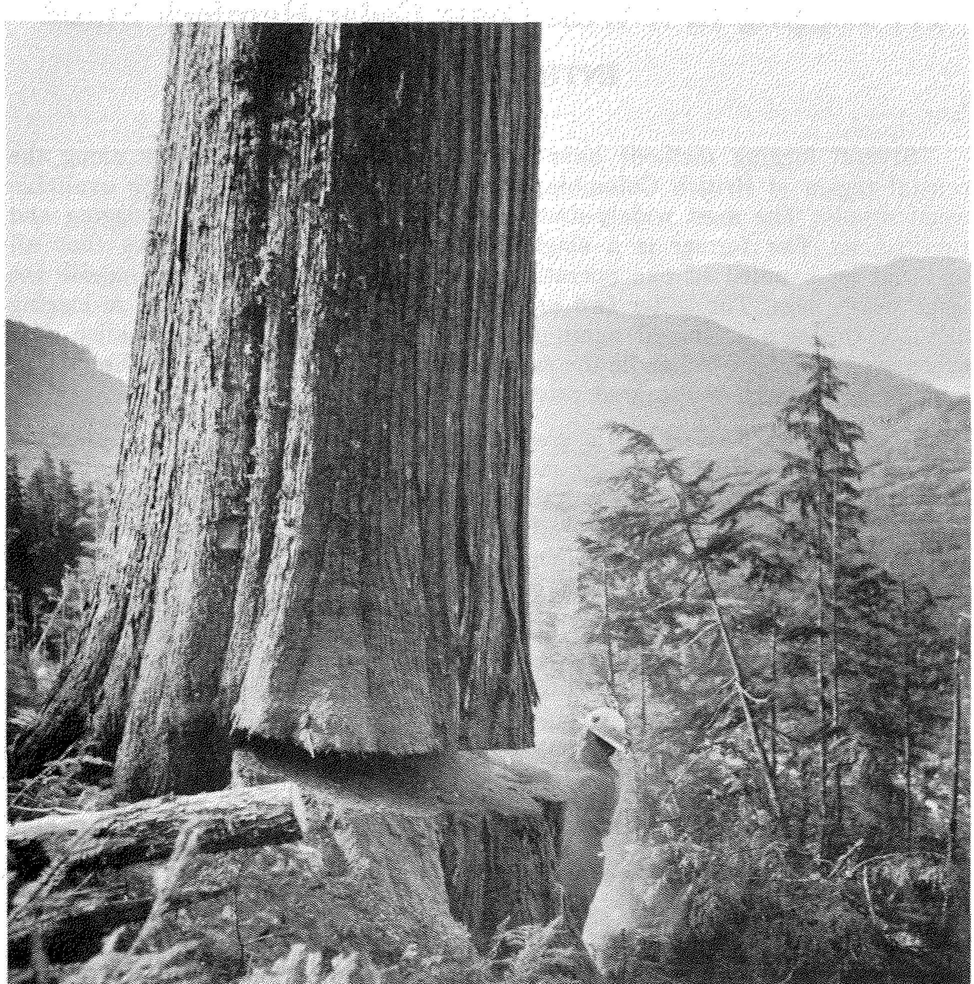
A study was undertaken by the Vancouver Laboratory of the Forest Products Research Branch to compare all aspects of two logging methods—pre-logging and re-logging. The study was conducted on the British Columbia Coast on one "setting" only, measuring 20.8 acres, and although the findings may not necessarily apply directly to other stands, nevertheless, it is suggested that they can be used as a guide both in appraising somewhat comparable areas and in investigating potential suitability for pre-logging on other areas.

The results of this study indicate that, from both the utilization and economic viewpoint, pre-logging was the better method on the study area. Five point seven per cent more wood volume per unit area was recovered by the pre-log method at a saving in direct wage costs of $0.66, or 14.4 per cent per 100 cubic feet. In addition, logging residue on the pre-logged area amounted to only 1,022 cubic feet per acre—40.2 per cent less than the residue volume on the re-logged area.

SOMMAIRE

Le laboratoire de Vancouver de la Direction des recherches sur les produits forestiers a entrepris une étude, afin de comparer tous les aspects de deux méthodes d'exploitation forestière: la coupe préalable et la coupe de récupération. L'étude a été exécutée en Colombie-Britannique, sur le littoral du Pacifique, dans une seule place mesurant 20.8 acres et bien que les constatations ne soient pas nécessairement applicables à d'autres peuplements, néanmoins, l'auteur est d'avis qu'elles pourraient servir à évaluer des régions comparables et à examiner l'opportunité d'avoir recours à la coupe préalable en d'autres endroits.

L'étude a révélé qu'en ce qui concerne le rendement et l'économie, la coupe préalable a donné de meilleurs résultats dans la place d'étude. Un volume de bois de 5.7 p. 100 supérieur a été récupéré par unité de surface grâce à la méthode de coupe préalable, ce qui a permis d'économiser directement sous forme de salaires 66 cents (ou 14.4 p. 100) par 100 pieds cubes. En outre, les rebuts d'abattage dans l'étendue où l'on a pratiqué la coupe préalable s'élèvent seulement à 1,022 pieds cubes à l'acre, soit 40.2 p. 100 de moins que le volume de rebuts dans l'étendue où l'on a pratiqué une coupe de récupération.



FRONTISPIECE—A "Humboolt" undercut in a large cedar—note the angle of the cut and also the low stump.

Pre-Logging In A West Coast Cedar-Hemlock Stand

INTRODUCTION

Several logging methods have been developed in recent years along the coastal region of British Columbia to increase the utilization of the available wood supply. The most widely-used methods are clean logging, re-logging and pre-logging. The former is a single operation method and requires that all material be handled in one operation with equipment designed to handle the large heavy logs. The latter two are dual-operation systems. In the re-logging method, the area is logged again after the main logging, using smaller, less expensive equipment to handle the small material (1). In pre-logging, the smaller understory material is removed prior to felling the main stand.

The method used is, to a great extent, governed by the type of stand involved. In the even-aged, single-story stands either clean logging or re-logging would appear to be the more suitable method. The uneven-aged, multi-storied stands, characteristic of much of the coastal forest area, are suited to either re-logging or pre-logging. Pre-logging permits a greater recovery of the understory material in the best possible condition.

These multi-storied stands are usually composed of a mixture of cedar, hemlock, and balsam[1] in varying proportions. It is the understory, an important part of the total stand volume, which is most severely damaged when felled and yarded with or after the main stand (2).

In order to determine which method—re-logging or pre-logging—was best-suited to handle a stand of this type, from both utilization and economic viewpoints, a study was carried out by the Vancouver Laboratory in a selected area near Stillwater, B.C.[2].

OBJECTIVES AND NATURE OF THE STUDY

The study was carried out on a 20.8-acre setting considered typical of both the stand and topographical conditions found on many of the mature and overmature cedar-hemlock areas of the west coast.

The study setting, as shown in Figure 1, was divided into four quarters—P1 and P2, the quarters to be pre-logged; and S1 and S2, the quarters to be re-logged. The ground was steep (average slope 50 per cent) and broken by rock outcrops and stream gulleys. P1 was somewhat steeper and rougher than the other quarters. The quarters were separated by the haul road and a well-marked line through the centre of the setting at right angles to the haul road.

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1 *Thuja plicata* Donn, *Tsuga heterophylla* (Raf.) Sarg., and *Abies amabilis* (Dougl.) Forb.

2 The then Powell River Company (now MacMillan, Bloedel and Powell River Ltd.) co-operated in this study and made this area available.

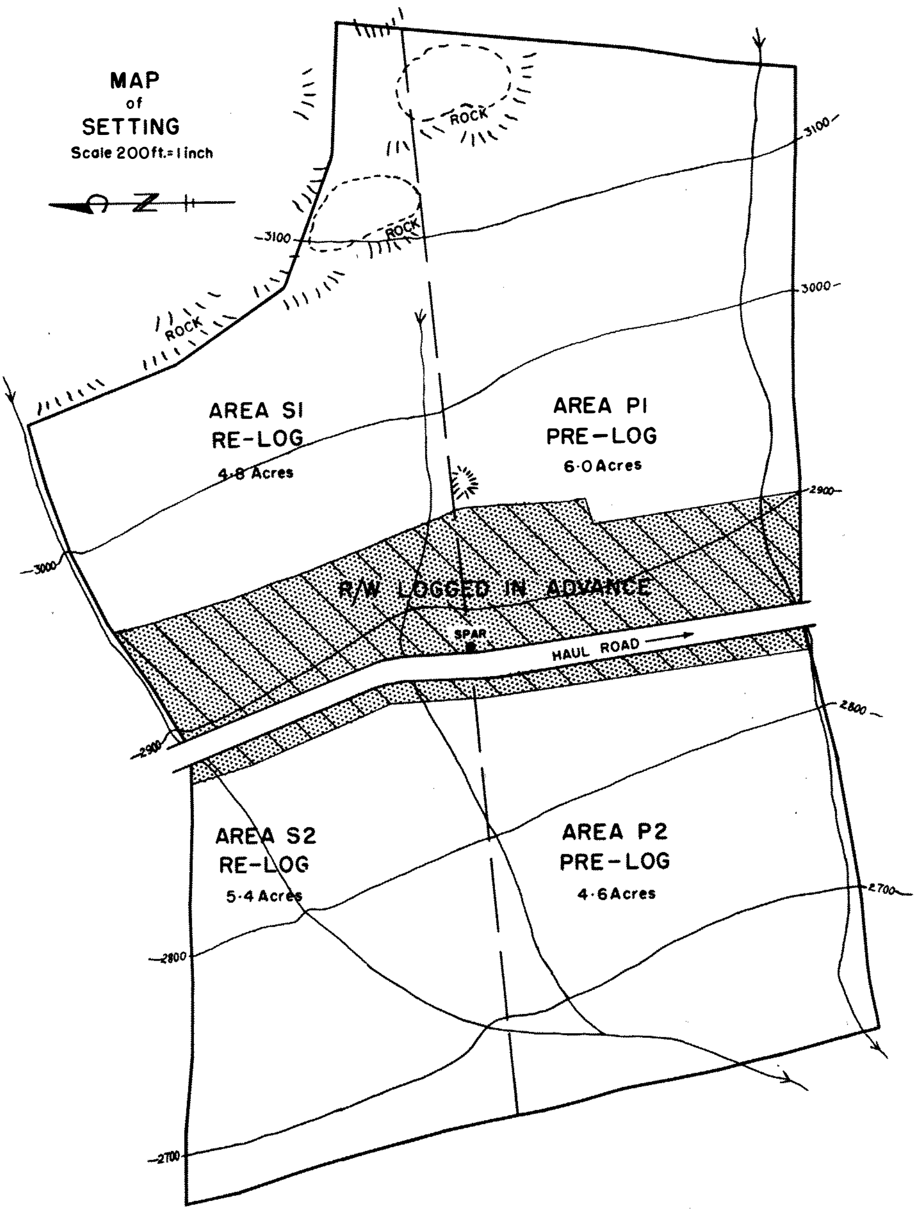

FIGURE 1—Site map for pre-logging and re-logging study comparisons.

Since both stand and topographic conditions were approximately comparable, it was possible to assess both logging methods readily with regard to the following objectives:

(1) To compare the losses through breakage and defect occasioned by each method.

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(2) To compare the effect of various factors, both inherent and induced, on the productivity of both methods.
(3) To compare the quality and quantity of material recovered by each method.
(4) To compare some of the costs involved with each method.
(5) To compare the residues remaining as waste after the application of each method.

The overall objective of the study was to determine which method was most effective from both the utilization and economic viewpoints. However, it must be emphasized that the results of the study apply only to this one setting, and could vary from area to area depending upon the stand and topographic conditions. Nevertheless, the results are indicative of what could be expected in other similar areas.

FIGURE 2—A typical west coast cedar-hemlock-balsam stand.

STAND CONDITIONS

The stand was typical of west coast mature and over-mature cedar-hemlock forests and, characteristically, contained an understory of the same species. The maximum d.b.h. measurements were: cedar 78 inches, hemlock 60 inches, and balsam 56 inches. The height of the dominant and co-dominant trees averaged 160 feet. The stand distribution by species and d.b.h. classes is shown in Table 1.

The understory was considered as trees of 22 inches d.b.h. and under to a minimum of 8 inches d.b.h. It comprised 70 per cent of the number of green trees and 30 per cent of the stand volume according to the cruise estimate.

A one hundred per cent cruise of the setting indicated a total net volume in standing green trees of 199,005 cubic feet based on the rough utilization standard of the British Columbia Forest Service (3). In addition, there was a further estimated net volume of 13,766 cubic feet in merchantable snags and windfalls. On a per acre basis this cruise indicated a total net volume of 10,299 cubic feet.

TABLE 1. STAND DISTRIBUTION PER ACRE BY SPECIES AND D.B.H. CLASSES

D.B.H. (in.)	Number of Trees per Acre				
	Hemlock	Balsam	Cedar	Total Trees	% Total
8 - 10	8.8	3.7	0.7	13.2	14.4
11 - 16	20.2	6.0	2.8	29.0	31.7
17 - 22	12.2	4.7	3.6	20.5	22.4
23 - 28	7.0	2.6	2.7	12.3	13.4
29 - 34	1.7	1.0	2.0	4.7	5.1
35 - 40	2.6	0.7	2.0	5.3	5.7
41 - 46	0.5	0.2	1.6	2.3	2.4
47 plus	0.3	0.2	3.9	4.4	4.9
Total trees	53.3	19.1	19.3	91.7	
% of total	58.3	20.8	20.9		100%

LOGGING METHOD

Two separate logging operations were involved with each logging method (Figure 1). On the pre-log Quarters P1 and P2, the understory was felled and removed prior to the felling and removal of the main stand. On the re-log Quarters S1 and S2, the stand was felled and yarded in the normal manner and then re-logged to recover the remaining merchantable material.

For convenience and clarity and in the absence of standard terms for these operations they will be referred to in this report as follows: for the pre-log method, the first operation will be referred to as pre-log smallwood and the second as pre-log largewood; for the re-log method, the first operation will be referred to as re-log largewood and the second as re-log smallwood.

The felling of the pre-log smallwood material or understory was done by day-rate fallers. Where possible, the tops were bucked at 4 inches d.i.b. In addition, these fallers felled all snags and bucked all windfalls—not only as a safety measure and to facilitate yarding, but also to permit the removal of the smaller merchantable pieces in the pre-log smallwood yarding. Because most of the pre-log smallwood material was destined for pulp at the company mill, the only log length stipulation was that none exceed 50 feet, which was the maximum length that could be handled efficiently at the mill.

To determine the effect of different felling practices on yarding and felling breakage losses, the pre-log smallwood trees on P1 were felled in such a way as to minimize felling breakage rather than to facilitate yarding. In P2 the reverse was done, and the trees were felled to "lead" to facilitate yarding.

Company policy required that stumps be kept as low as possible regardless of butt swell. This policy not only increased the degree of utilization but also eliminated the high stump hazard in felling and yarding. It was strictly enforced in felling the pre-log smallwood material since high stumps from these trees could be a very serious factor, affecting felling breakage in the larger, more valuable, trees of the main stand.

Both yarding operations on each area were carried on with a 90-foot portable steel spar, mounted on a modified logging truck chassis, and powered by a 150-hp. diesel motor. The loading was "hot" with a Skagit SJ4RT loader-yarder fitted with standard loading tongs.

FIGURE 3—A 90-foot portable steel spar.

Considerable care was taken in selecting yarding "road" locations for the pre-log smallwood yarding. Wherever possible the lines were run through the larger openings in the remaining standing timber in such a manner that the main line could "siwash" the standing trees and permit the logs being yarded to roll around these trees rather than to become entangled behind them.

STUDY PROCEDURES

The same study procedures were used in all phases of the experiment. All logs, snags and windfalls were scaled and identified by species after felling and bucking, and after yarding. Gross and net scales were recorded with the reasons for any deductions. Because it provides a more accurate estimate of smallwood volumes as well as a more uniform basis for comparison than the B.C. Log Scale, the B.C. Cubic Scale was used for all scale measurements.

In addition to the scale data, the yarding distance and the number and species of each log were recorded for each turn.

Stop watches were used to measure the various times of the yarding operations, which were recorded under the following headings:

(1) Haul back—time required to return the rigging from the landing to the hook-up point of the next turn.
(2) Stop chokers—time taken by the chokermen to reach the chokers after the rigging had stopped.
(3) Hook-up—time required to choke sufficient logs for a turn.
(4) Haul—time spent in yarding the turn to the landing.
(5) Unhook chokers—time required to remove the chokers at the landing.
(6) Hang-up—time spent in freeing the turn from entanglements during the haul.
(7) Landing delays—abnormal delays at the landing.
(8) Other delays—all other times not included in the above times.

HARVESTING LOSSES

The losses presented in this report are based on the gross tree volume, which is the total volume of the tree to a 4-inch top for the pre-log smallwood trees, and to a top of 20 per cent of the d.b.h. for the others, with no deductions made for defect or decay. Throughout the logging industry on the coast, losses are generally expressed as a percentage of the official government scale. This is usually the net water scale which corresponds very closely to the net volume loaded at the landing. On such a basis, percentage losses would be appreciably higher than those based on the gross tree volume used in this report.

1. Pre-log Smallwood

Quarters P1 and P2 were considered separately because of the different felling methods used.

On P1, 363 trees with an average gross volume of 69.9 cubic feet were felled, and on P2, 219 trees were felled with an average gross volume of 67.2 cubic feet.

Felling and Bucking—The classification by species of the losses incurred in felling and bucking the pre-log smallwood trees is presented in Table 2. In this case the gross tree volume was based on a close utilization standard—to a 4-inch top (3). However, due to felling breakage the average top recovered for these trees was 8.5 inches.

TABLE 2. CLASSIFICATION OF FELLING LOSSES—PRE-LOG SMALLWOOD TREES

(Shown as a Percentage of Gross Tree Volume)

—	Hemlock		Balsam		Cedar		All Species	
	P1	P2	P1	P2	P1	P2	P1	P2
No. of Trees	234	158	76	49	53	12	363	219
Gross Tree Volume (cu. ft.)	16,487	10,800	5,296	3,267	3,609	657	25,392	14,724
% Loss								
Defect								
Logs	4.6	2.4	0.7	0.3	3.7	1.6	3.7	1.9
Tops and Chunks	4.0	1.9	0.2	—	—	—	2.6	1.4
Breakage								
Logs	0.6	1.5	0.6	2.2	0.2	0.5	0.6	1.6
Tops and Chunks	15.2	11.2	12.0	10.8	18.4	11.8	15.0	11.2
Net Vol. Before Yarding								
%	75.6	83.0	86.5	86.7	77.7	86.1	78.1	83.9
cu.ft.	12,453	8,969	4,580	2,831	2,806	565	19,839	12,365

It will be seen from this table that the greatest loss was from broken tops, and that in this respect cedar suffered the highest percentage loss. Loss from defect was greatest in hemlock, much of which was infected with mistletoe.

Although the felling on P1 was done in such a manner as to reduce breakage, total felling breakage on this quarter was greater due to the excessive top breakage caused by the rougher ground. Felling to "lead" did result in a higher breakage loss in the logs on P2.

The percentage volume classification by species of the pre-log smallwood material after felling and bucking was:

P1 { hemlock 63 per cent
balsam 23 " "
cedar 14 " "

P2 { hemlock 72 per cent
balsam 23 " "
cedar 5 " "

Yarding and Loading—Yarding losses caused a further 8.2 per cent loss on P1 and 2.3 per cent on P2. Logs overlooked around the edges of the settings were almost equal in number and volume on each quarter and accounted for practically all the yarding losses on P2. The higher loss on P1 was due to the many hang-ups occurring on this quarter and the resulting breakage when freeing these hang-ups. The losses occurring in loading were so small that they could be considered as nil.

Because of this series of losses only 69.9 per cent of the gross tree volume was recovered on P1 and 81.6 per cent on P2.

Although the normal practice was to limb the pre-log trees after felling, 15 of these trees were left unlimbed in the southwest corner of P2 to determine to what extent the limbs could be removed during yarding. However, very few of the limbs were broken off in yarding and it was necessary to complete the limbing at the landing. This would indicate that all limbing should be done at the time of felling.

2. Pre-log Largewood

The pre-log largewood was that part of the stand remaining on P1 and P2 after the pre-log smallwood material had been removed.

FIGURE 4—A cold-deck of pre-logged material—note remaining main stand. (Nanaimo Lakes Operation, Crown-Zellerbach Canada, Limited.)

Felling and Bucking—The pre-log largewood trees were felled by contract fallers—a different set in each quarter. Because only the large trees remained the fallers were able to fell up to 30 per cent more volume per working day than they did on normal settings. The fallers were of the opinion that, although the general ground conditions had been improved by pre-logging, it was necessary to clear more debris from around the base of the trees in order to obtain

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the very low stumps required by company regulations. The broken tops from the pre-log smallwood trees tended to accumulate on the upper side of the large trees, and had to be removed before felling commenced. Another point they noted was that more care had to be taken in "placing" the tree as the pre-log smallwood stumps had to be avoided and no small trees were available to cushion the fall of the large trees.

The losses suffered by the pre-log largewood trees were considered as a percentage of the gross tree volume with no deductions for defect or decay and, as previously stated, are based on a top utilization standard of 20 per cent of the d.b.h. This standard was seldom attained. The top diameters as actually cut are compared with this standard in Table 3.

A point to be noted in this table is that in all diameter classes cedar, the most brittle species, broke at a smaller top than did either hemlock or balsam.

The classification of the losses suffered in felling and bucking (excluding snags and windfalls) is shown in Table 4.

In this report, breakage caused by impact with the ground is classified as "primary breakage"; that incurred in bucked logs when hit by other trees is classified as "secondary breakage"; and "chunks" are those pieces bucked from the stem to eliminate broken or defective sections.

TABLE 3. CLASSIFICATION OF TOPS—PRE-LOG LARGEWOOD

(Curved Values)

D.B.H. (in.)	20% of D.B.H. (in.)	P1 Actual Top as Measured (in.)			P2 Actual Top as Measured (in.)		
		Hemlock	Balsam	Cedar	Hemlock	Balsam	Cedar
20	4	11	10	9	11	12	10
25	5	13	12	12	13	14	12
30	6	16	15	14	15	16	14
35	7	19	18	17	18	19	17
40	8	23	22	19	20	—	19
45	9	26	26	22	23	—	22
50	10	30	31	24	—	—	24
55	11	—	—	27	—	—	27
60	12	—	—	30	—	—	30
65	13	—	—	32	—	—	34
70	14	—	—	35	—	—	37

The high volume of defect losses in hemlock and cedar were concentrated in relatively few trees containing 20 per cent or more defect. These trees were severely shattered in felling and produced a negligible amount of merchantable material. They also contributed to the high felling breakage incurred by these two species.

Despite the many stumps remaining from the pre-log smallwood trees, relatively few of the large trees (9.2 per cent causing 6.6 per cent of the total breakage) were affected by them. This could have been due to the extra care taken by the fallers in "placing" the trees, as well as the very low stumps from the pre-log smallwood trees.

TABLE 4. CLASSIFICATION OF FELLING AND BUCKING LOSSES—PRE-LOG LARGEWOOD TREES

(Shown as a Percentage of Gross Tree Volume)

—	Hemlock		Balsam		Cedar		All Species	
	P1	P2	P1	P2	P1	P2	P1	P2
No. of Trees	48	39	30	16	43	64	121	119
Gross Tree Volume (cu. ft.)	17,945	11,165	11,019	4,931	19,298	39,522	48,262	55,618
% Loss								
Defect								
Logs	7.2	5.5	3.2	0.6	9.3	12.3	7.2	9.9
Tops and Chunks	3.2	4.9	1.6	—	2.6	0.7	2.6	1.5
Breakage—Logs								
Primary	2.6	1.4	2.0	0.8	9.3	7.3	5.1	5.5
Secondary	0.1	3.1	1.7	2.0	0.6	0.7	0.7	1.3
Tops and Chunks	14.1	10.3	13.2	15.8	12.4	14.9	13.2	14.1
Net Vol. Before Yarding								
%	72.8	74.8	78.3	80.8	65.8	64.1	71.2	67.7
cu.ft.	13,060	8,353	8,629	3,984	12,695	25,319	34,384	37,656

Figure 5—Cedar suffered severe breakage.

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Another loss factor noted, but which was difficult to measure accurately, was that resulting from not using the "Humbolt" type undercut in felling. In this method, the faller takes the undercut from the stump rather than from the butt log and so makes a clean, straight butt cut. The crew of fallers using the "Humbolt" method made a more valuable butt log than did those using the older method of taking the undercut from the butt log (see Frontispiece).

Yarding—A further loss of 7.3 and 4.6 per cent of the gross volume on P1 and P2 respectively occurred in yarding, with the result that only 63.9 and 63.1 per cent of the gross tree volume of the pre-log largewood trees was recovered on P1 and P2 respectively.

The yarding losses were confined almost entirely to logs which had been damaged in felling, and in this regard cedar suffered the greatest loss. Almost every cedar log which had been shattered in any way in felling suffered a further loss in yarding. The higher percentage loss on P1 as compared to P2 was due to the buffeting against rocks and stumps during the downhill yarding.

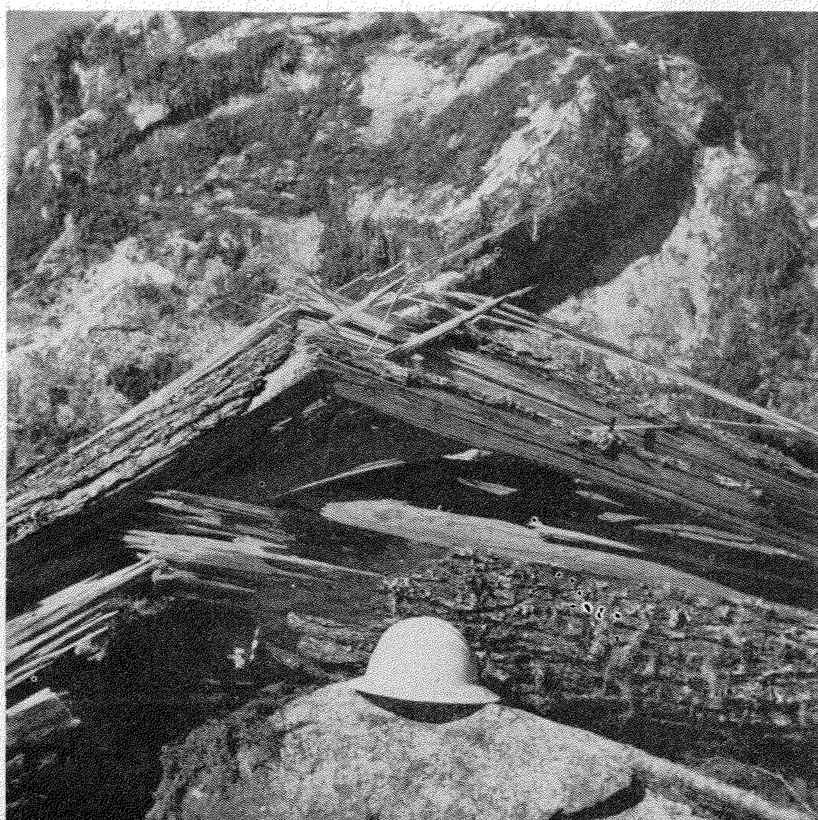

FIGURE 6—Rough ground contributed to breakage.

Loading—Loading losses were small and almost impossible to measure accurately. Nevertheless, it was noted that the small losses which developed in loading were concentrated in the larger, more valuable, logs and invariably affected the most valuable part—the outside clear portion. This damage was caused by the loading tongs pulling out of the log and, in so doing, tearing out a slab. It would appear that the little extra time required to "strap" the large logs would be more than offset by the saving of high-grade material. Another method that could be used to minimize this type of damage is the use of log grapples in loading instead of standard tongs (4).

3. Re-log Largewood

The stand composition on Quarters S1 and S2 was similar to that on the pre-log quarters. The trees on these quarters were felled in the normal manner. That is, the fallers worked back and forth across the quarters felling and bucking all but the smallest trees as they came to them, i.e. those approximately 10-inch d.b.h. and under, although most of the latter were destroyed when hit by the falling larger timber. Following this operation the felled and bucked material was yarded; the few small trees left standing being either pulled over or broken off.

Although it was felt that the presence of the smaller trees and the absence of stumps would reduce breakage of the tops of the larger trees, such was not the case. The top measurements were almost identical to those shown in Table 3 for the pre-log largewood trees. This would indicate that pre-logging need not increase top breakage in the main stand provided proper care is exercised in felling this part of the stand.

Felling and Bucking—The classifications of the losses suffered in felling and bucking the re-log largewood material (excluding snags and windfalls) is shown in Table 5.

TABLE 5. CLASSIFICATION OF FELLING AND BUCKING LOSSES—RE-LOG LARGEWOOD TREES

(Shown as a Percentage of Gross Tree Volume)

—	Hemlock		Balsam		Cedar		All Species	
	S1	S2	S1	S2	S1	S2	S1	S2
No. of Trees	62	133	80	110	60	136	202	379
Gross Tree Volume (cu. ft.)	13,101	25,100	14,344	15,829	29,026	57,994	56,471	98,923
% Loss								
Defect								
Logs	4.8	6.1	1.2	1.4	7.4	9.8	5.2	7.5
Tops and Chunks	3.1	2.2	0.2	0.7	—	4.5	0.8	3.3
Breakage—Logs								
Primary	2.3	2.0	1.6	0.5	8.5	6.2	5.5	4.0
Secondary	3.1	0.1	0.5	0.2	1.4	1.2	1.4	1.0
Tops and Chunks	12.2	14.3	13.2	13.5	14.1	11.9	13.4	12.7
Net Vol. Before Yarding								
%	74.5	75.3	83.3	83.7	68.6	66.4	73.7	71.5
cu.ft	9,760	18,909	11,948	13,250	19,912	38,523	41,620	70,682

As with the pre-log quarters a very high percentage of the losses was concentrated in relatively few trees containing 20 per cent or more defect. These trees disintegrated on hitting the ground and produced little if any merchantable wood. Here again cedar suffered the most and balsam the least from defect and breakage.

Loss in broken tops was the largest single loss factor affecting all species.

Only 2.9 per cent of the trees were damaged in falling across stumps, although the stump damage did account for almost as high a percentage loss as in the pre-log quarters—6.2 per cent for the former as compared to 6.6 per cent for the latter.

FIGURE 7—A break is bucked from the stem.

Yarding and Loading—Yarding damage accounted for the loss of an additional 5.9 and 9.4 per cent of the gross tree volume on S1 and S2 respectively. As in the pre-log largewood yarding, cedar was the species most seriously affected by yarding damage. The higher loss on S2 was due primarily to a sharp gully which cut across the quarter almost at right angles to the direction of yarding and caused many serious hang-ups and additional breakage.

Loading damage was similar to that previously noted for the pre-log largewood material.

4. Re-log Smallwood

The greater part of this material, which accounted for 10.0 per cent of the total volume recovered from S1 and S2, consisted of the small trees which were pulled over or broken off in the re-log largewood yarding. The remainder consisted of logs broken and left from this yarding operation.

Prior to yarding the re-log smallwood material, salvage buckers went over both quarters, bucked the pulled-over and broken trees into logs, and trimmed the ends of the broken logs left from the previous yarding operation.

The minimum size piece considered merchantable by the company was 12 feet in length to a 4-inch top for the pulp species (hemlock and balsam), and 16 feet to a 10-inch top for cedar, depending on its quality as saw-timber.

Because this material was made up of salvage from previously damaged material, the only loss that was considered occurred in the form of bucked logs overlooked in the re-log smallwood yarding and left as waste.

5. Snags and Windfalls

The net volume contained in merchantable snags and windfalls amounted to 9.3 and 7.1 per cent of the total net volume before yarding on the pre-log and re-log quarters respectively.

This material suffered severely in yarding and accounted for only 1.5 and 3.9 per cent of the total net volume recovered from these areas.

On the pre-log quarters, all the snags were felled and the windfalls bucked by the pre-log smallwood fallers, although only the smaller merchantable pieces were removed in the pre-log smallwood yarding. More of this material might have been recovered had it been removed in the pre-log smallwood yarding, rather than being left to suffer additional damage during the felling and yarding of the pre-log largewood. It was noted that the larger windfalls constituted a definite hazard contributing to yarding breakage and hang-up time during the pre-log smallwood yarding. This hazard could have been reduced by removing all the windfalls during the pre-log smallwood yarding.

YARDING

As previously stated, all phases of yarding were done with the same machine —a 90-foot portable steel spar. The only equipment change made during the experiment was in the chokers. The $\frac{5}{8}$-inch chokers used in the smallwood yarding were replaced with $\frac{3}{4}$-inch chokers for the largewood yarding.

The yarding operations in order of occurrence were: pre-log smallwood, pre-log largewood, re-log largewood, and re-log smallwood.

A normal high-lead yarding crew consists of a hook-tender or foreman, an engineer, a rigging slinger, a chaser, a signalman and one or more chokermen. The chaser is often eliminated on hot loading operations by having a member of the loading crew act as chaser in addition to his loading duties.

Since this was the company's initial attempt at high-lead pre-logging, several changes were made in the size of the yarding crew during the pre-log smallwood yarding to determine the most efficient crew size for this type of work. The maximum crew used was eight men and the minimum crew four men. Because of this variation in crew size it was necessary to base the results of the pre-log smallwood yarding on different average crew sizes for each quarter—P1 had an average of 6.5 men and P2 an average of five men. The results of all other yarding operations are based on a five-man crew. Some basic data pertaining to the recovered pre-log smallwood material, as well as the re-log smallwood and the largewood material, are shown in Table 6.

TABLE 6. BASIC DATA ON RECOVERED MATERIAL

—	Smallwood				Largewood			
	Pre-log		Re-log		Pre-log		Re-log	
	P1	P2	S1	S2	P1	P2	S1	S2
Total vol. yarded (cu.ft.)	19,681	13,320	6,260	4,720	36,433	40,166	35,253	63,344
No. of logs	535	389	406	273	285	322	355	724
Av. log volume (cu.ft.)	36.8	34.2	15.4	17.3	127.8	124.8	99.2	87.5
Av. turn volume (cu.ft.)	58.9	62.2	31.9	32.8	176.8	185.5	140.2	143.9
Av. yarding distance (ft.)	515	405	425	410	515	405	425	410
Production rate (cu.ft./man hr.)	53.3	85.0	55.4	47.8	157.1	189.6	152.4	160.1

1. Pre-log Smallwood

Quarters P1 and P2 are considered separately because of two factors, both of which had a definite effect on the results—one, the crew differed in size between quarters, and two, the yarding was downhill on P1 and uphill on P2.

The time breakdown of the various operational phases of the pre-log smallwood yarding operation is shown in Table 7 as the average time in crew-minutes per 100 cubic feet and the per cent of total time for each phase.

TABLE 7. PRE-LOG SMALLWOOD YARDING

Breakdown of Total Time Based on Crew Minutes and Net Cubic Volume

Phase of Operation	Av. Time per C cu.ft. (Min.)		Per Cent of Total Time	
	P1	P2	P1	P2
Haul back	1.0	0.9	5.7	6.1
Stop chokers	0.8	0.8	4.7	5.8
Hook-up	4.5	3.5	26.1	24.6
Haul	3.3	2.1	19.0	15.0
Unhook chokers	1.3	1.3	7.8	9.0
Hang-ups	2.0	0.5	11.3	3.3
Landing delays	0.7	0.2	3.9	1.2
Other delays	3.7	4.9	21.5	35.0
TOTALS	17.3	14.2	100.0%	100.0%

It will be noted in the table that although there was little difference between quarters in regard to productive times, there was considerable difference in the non-productive times, which were hang-ups, landing and other delays.

Another factor to be considered is that it required 17.3 minutes to yard 100 cubic feet on P1 and only 14.2 minutes for an equal volume on P2. The main reasons for this difference were that the average yarding distance was greater on P1 than on P2, and that hang-ups were more frequent and severe on P1 than on P2.

Lost time per turn due to hang-ups increased much more with increased yarding distances on P1 than on P2. This time varied on P1 from 0.12 minute per turn for distances up to 200 feet, to 3.21 minutes per turn for distances beyond 600 feet, and averaged 1.15 minutes per turn for the quarter. On P2 the variation was from 0.26 to 0.39 minute per turn for comparable distances, with an average time of 0.28 minute. The reason for this increase between quarters was that positive control of the turns was difficult when yarding downhill on such steep ground and many turns, particularly from the longer yarding distances, became entangled behind the standing trees and larger windfalls.

Hang-ups, especially on P1, could have been reduced by removing all the windfalls as the yarding progressed. The merchantable pieces could have been yarded to the landing and the unmerchantable pieces removed from the yarding roads. It was noted during the study that once a road had been cleared of windfalls the crew had much less difficulty moving the turns around the standing trees.

Crew size is a very important economic factor, especially when handling small material. Despite the extra men—up to eight in P1—hook-up time, which was the largest component of productive time, was greater on P1 than on P2, although working conditions for the chokermen were similar in both areas. The reason for this difference may have been that the chokermen were inexperienced when starting on P1 but had gained some experience by the time the yarding had progressed to P2. A four-man crew was tried on P2 for two days and a good production rate maintained. However, it was felt that from both the production and safety viewpoints, a five-man crew was the ideal unit for this work.

The extra landing delays noted on P1 were due to a large rock near the landing which made it difficult for the engineer to "land" the turns.

The largest single item affecting "other delays" was the time required to change roads. Other factors were repairs, removing logs and trees, planning and miscellaneous delays.

The effect of the total delay, or non-productive times, on yarding time per 100 cubic feet is shown in Table 8, and is illustrated graphically in Figure 8. It will be seen from Figure 8 that there was an increase in yarding time per 100 cubic feet for all volume turns on P1 as compared to P2. The information presented applies to a yarding distance of 550 feet, but similar results were obtained for other yarding distances. If considered on the basis of man-minutes rather than crew-minutes per 100 cubic feet the difference in yarding time is increased again because of the larger crew employed on P1.

Turn volume decreased considerably with yarding distance on P1, whereas little difference was noted on P2. This decrease was due to two factors—one, the turns from the greater distances were subject to more frequent hang-ups and breakage, and two, these same turns suffered from logs slipping out of the chokers on the steeper parts of the slope.

The percentage of the total number of turns, the total recovered volume, and the total time by turn volume classes is shown in Table 9.

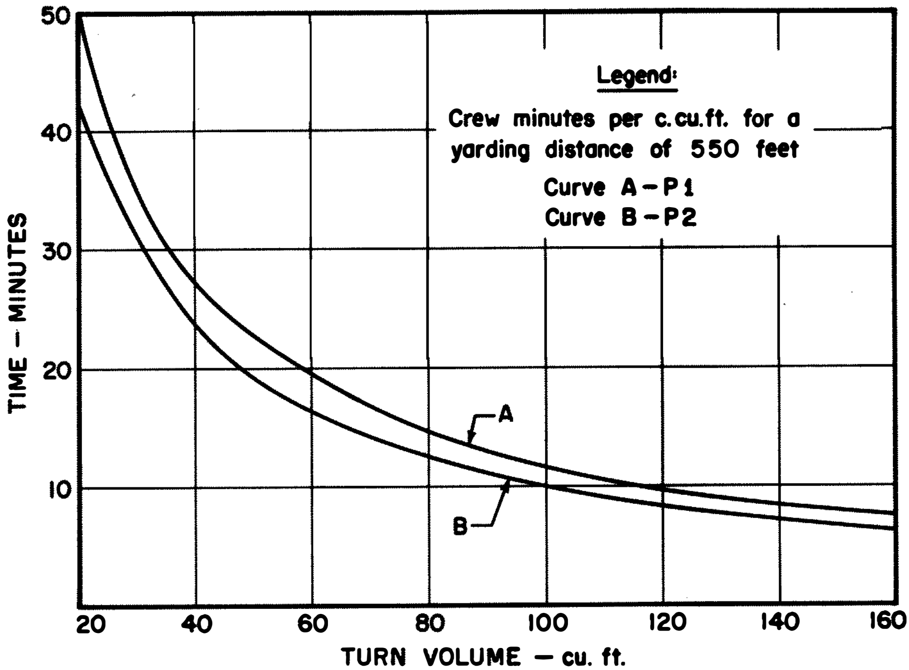

FIGURE 8—The effect of Turn Volume on Yarding Time.

TABLE 8. THE EFFECT OF TURN VOLUME ON YARDING TIME

Crew Min. per C cu.ft. for a Yarding Distance of 550 ft.*

Turn Volume (cu.ft.)	Crew Minutes per C cu.ft.		Man Minutes per C cu.ft.	
	P1	P2	P1	P2
20	50.8	43.0	330.2	215.0
40	27.1	23.6	176.1	118.0
60	19.3	15.8	125.4	79.0
80	14.5	12.4	94.2	62.0
100	11.5	10.3	74.7	51.5
120	9.8	8.5	63.7	42.5
140	8.4	7.2	54.6	36.0
160	7.5	6.2	48.7	31.0

*To convert above information to a per M f.b.m. (B.C. Log Scale) basis, multiply turn volume by 5 and yarding times by 2.

TABLE 9. PERCENTAGE OF THE TOTAL NUMBER OF TURNS, TOTAL TIME, AND TOTAL VOLUME FOR VARIOUS TURN VOLUME CLASSES

Turn Volume Class (cubic feet)	Turns %		Time %		Volume %	
	P1	P2	P1	P2	P1	P2
10 and under	4.3	4.1	3.9	3.9	0.6	0.4
10.1 - 20.0	13.7	14.9	13.4	13.2	3.6	4.0
20.1 - 40.0	25.5	17.0	27.1	18.0	12.6	7.9
40.1 - 60.0	19.7	21.7	19.7	21.4	16.7	17.3
60.1 - 80.0	13.7	13.6	14.0	14.8	16.2	15.5
80.1 - 100.0	7.9	10.9	7.8	10.9	12.1	16.4
100.1 - 140.0	8.8	11.6	8.4	11.6	17.3	22.1
140.1 - 180.0	3.7	4.8	3.6	4.7	9.4	11.9
180.1 - 220.0	1.2	1.4	1.0	1.5	4.3	4.5
Over 220	1.5	—	1.1	—	7.2	—
TOTAL (per cent)	100	100	100	100	100	100

This table emphasizes further the effect of the smaller volume turns on P1. On this quarter, turns containing 40 cubic feet or less accounted for 43.5 per cent of the total number of turns, 44.4 per cent of the total time, and only 16.8 per cent of the total recovered volume. On P2, turns of the same volume accounted for only 36.0 per cent of the total number, 35.1 per cent of the total time, and 12.3 per cent of the total recovered volume.

On the steep ground existent on this setting, the analysis of the data indicates that yarding downhill from distances in excess of 600 feet was particularly costly. The pre-log material beyond this distance could well have been left standing and removed along with the pre-log largewood. On P1, it represented only 11.2 per cent of the recovered pre-log smallwood volume, yet accounted for 27.2 per cent of the total time. However, on P2, where yarding was uphill, delays were not as significant as on P1 and the rate of production with increased yarding distances was a function of the haulback and haul times rather than the delay times.

Loading—All loading was done with the same unit—a Skagit SJ4RT mobile loader and a three-man loading crew. Because of the steep ground and small landing it was necessary to have the loading unit available at all times to remove the logs as they were yarded. Consequently, all but the re-log smallwood logs were loaded on to trucks almost immediately they were yarded. Nevertheless, except for the re-log smallwood, at no stage in the yarding was the loading unit working to capacity for more than a few minutes at a time. Because of these conditions loading did not affect the productive capacity of the overall operation so no detailed analysis of the loading operation was made. Therefore, only the number of hours the unit spent at the landing during each yarding operation was recorded to determine the loading costs.

Some Observations—With an experienced pre-logging crew, lost time due to hang-ups, road changes and planning would be reduced and a corresponding increase in productive time and capacity could be expected. More experienced pre-log fallers could position the logs for easy yarding by felling towards possible yarding roads and bucking the logs in a position where they could be readily choked. In this regard, the results of this study indicate that felling to lead was the more efficient method of felling the pre-log material.

Turn volume can be controlled to some extent by the felling practice. In pre-logging, the small trees could be felled as close together as possible and so permit several logs to be choked in the majority of turns.

Safety Considerations in Pre-logging—Safety is now as important a factor as production on logging operations. Any new logging method presents new safety hazards and, for this reason, particular care was taken to note all new hazards peculiar to this method.

Hang-ups in felling were not as frequent as had been expected—two on P1 and one on P2. These could possibly have been eliminated had the fallers not adhered so strictly to the 22-inch d.b.h. cutting limit.

Broken branches left hanging in the largewood trees will constitute a major hazard to the pre-log smallwood yarding crew and the largewood fallers. Although none were noted in this operation, it is a hazard which should not be overlooked.

Four largewood trees were pulled over in yarding on P1, but none on P2. These were pulled over in the direction of yarding but were not considered by the crew to constitute as great a hazard as logs jarred loose on steep hillsides during normal high-lead yarding. The crew was aware of the hazard and acted accordingly.

Wind is a factor that must be considered in all subsequent operations after the stand is opened up by felling the pre-log smallwood material.

2. Largewood—Pre-log and Re-log

The only equipment change made before commencing the largewood yarding was to replace the ⅝-inch chokers used in pre-logging with ¾-inch chokers.

The largewood yarding crew consisted of five men—a hook tender, an engineer, a signalman, a rigging slinger, and a chokerman. The second loader from the loading unit acted as a chaser in addition to his loading duties.

The basic information pertaining to the largewood material on all quarters is presented in Table 6. Quarters P1 and S1 were above the haul road and in these areas yarding was downhill, whereas the reverse was the case in Quarters P2 and S2.

The most important factor as far as the largewood material was concerned was that the average log volume, and as a result the average turn volume, was greater in the largewood yarding on the pre-log than on the re-log quarters. This was a direct result of the removal of the smaller material from the pre-log areas in the pre-log smallwood yarding, thus leaving only the larger material to be removed in the largewood yarding operation.

The breakdown of the yarding time by quarters is shown in Table 10 as the average time in crew-minutes per 100 cubic feet and the percentage of total time for each phase of the largewood yarding operation.

Hook-up, again, was the greatest time-consuming factor on all quarters. The greater hook-up time required on P1 and P2 appeared to have been caused by the absence of small material which allowed the larger logs to lay close to the ground and made "choker setting" difficult. Preparing choker holes under the larger, more difficult, logs in advance of yarding might effectively reduce this time.

FIGURE 9—A pre-log largewood cedar butt log is yarded to the landing.

TABLE 10. LARGEWOOD YARDING

Breakdown of Total Time Based on Crew Minutes and Net Cubic Volume

Phase of Operation	Pre-log Area				Re-log Area			
	Average Time per C cu.ft./min.		Per Cent of Total Time		Average Time per C cu.ft./min.		Per Cent of Total Time	
	P1	P2	P1	P2	S1	S2	S1	S2
Haul back	0.3	0.2	4.9	4.3	0.3	0.4	4.8	5.7
Stop chokers	0.2	0.2	3.2	3.5	0.3	0.2	3.9	3.2
Hook-up	2.2	2.6	31.4	45.6	1.8	2.3	25.6	30.7
Haul	1.1	0.9	16.2	15.6	1.2	1.2	16.8	16.4
Unhook chokers	0.4	0.4	5.5	6.3	0.5	0.6	7.2	8.6
Hang-ups	0.6	0.1	9.1	2.3	0.3	0.6	4.0	7.9
Landing delays	—	—	0.7	0.7	1.1	0.4	15.1	4.8
Other delays	2.0	1.2	29.0	21.7	1.6	1.8	22.6	22.7
TOTALS	6.8	5.6	100.0	100.0	7.1	7.5	100.0	100.0

The excessive landing delays on S1 were due to the large rock at the landing which made it difficult for the engineer to "land" the turns. It was estimated that a considerable overall saving would have been realized had this rock been removed by blasting prior to yarding.

"Other delays", differing little between quarters, included such items as road changes, repairs, etcetera.

The most significant factor to be noted in this table is the total time required to yard a unit volume from each quarter; in this respect, the pre-logged quarters showed to advantage. Times required to yard 100 cubic feet were 6.8 and 5.6 minutes on P1 and P2 respectively, whereas 7.1 and 7.5 minutes were required to yard the same volume on S1 and S2 respectively.

FIGURE 10—A load of pre-log largewood logs.

The effect of two factors—the longer average yarding distance on P1, and the greater hook-up time on P1 and P2 as compared to S1 and S2—became evident in the analysis of the yarding time per 100 cubic feet as related to turn volume and yarding distance. This analysis is shown in Table 11. Both factors caused an increase in the yarding time required for turns of comparable volume from the quarter or quarters concerned. However, the adverse effect of these factors was more than offset by the effect of turn volume. Because only large logs were available (see Table 6) on the pre-log area, the average turn volume was much higher than on the re-log area (approximately 180 cubic feet compared to 140 cubic feet). Consequently, fewer small volume turns were handled on the former than on the latter area, making the yarding time or cost per 100 cubic feet lower on the pre-log area.

The effect of this time difference as related to average turn volume is evidenced further by the information presented in Table 12. This table shows the percentage of total turns, of total time, and of total volume by turn volume classes for each quarter.

TABLE 11. YARDING TIME PER 100 CUBIC FEET AS RELATED TO TURN VOLUME AND AVERAGE YARDING DISTANCE*

Turn Volume (cu.ft.)	Crew Minutes per C cu.ft.			
	P1	P2	S1	S2
60	—	—	16.2	—
70	17.4	14.0	14.7	15.5
80	15.9	11.8	13.3	13.8
120	10.6	8.2	8.9	9.1
140	8.8	7.3	7.4	7.6
160	7.5	6.7	6.3	6.6
180	6.6	6.1	5.4	5.9
200	5.9	5.6	4.8	5.3
240	5.0	4.8	4.1	4.6
280	4.5	4.2	3.7	4.1
320	4.1	3.6	3.4	3.8
360	3.7	3.1	3.2	3.4
400	3.5	2.7	3.0	3.1
440	3.2	2.3	—	2.9
480	3.0	2.0	—	2.7
520	2.9	1.8	—	2.5

* For average yarding distance see Table 6.

TABLE 12. LARGEWOOD YARDING

Percentage of the Total Number of Turns,

Total Time and Total Volume for Various Turn Volume Classes

—	Turn Volume Class—Cubic Feet				
	0-100.0	100.1-200.0	200.1-300.0	300.1-400.0	Over 400
% of Total Turns					
P1	25.3	42.9	19.8	7.4	4.6
P2	24.3	33.6	27.6	9.2	5.3
S1	38.6	39.0	17.1	2.2	3.1
S2	32.9	44.2	18.0	3.6	1.3
% of Total Time					
P1	25.0	42.3	19.5	8.5	4.7
P2	22.3	32.4	30.6	10.2	4.5
S1	37.1	40.0	16.7	2.8	3.4
S2	32.2	43.9	18.4	4.1	1.4
% of Total Volume					
P1	9.8	35.9	26.9	14.0	13.4
P2	9.4	25.1	35.2	16.2	14.1
S1	16.1	39.5	29.6	5.3	9.5
S2	14.2	43.3	29.6	8.3	4.6

It will be noted that a greater percentage of turns, time and volume are involved in the lower turn volume classes in the re-log than in the pre-log area.

3. Re-log Smallwood

The re-log smallwood yarding commenced on Quarters S1 and S2 immediately the salvage buckers were finished. The crew and equipment were the same as that used in the largewood yarding except that the $\frac{3}{4}$-inch chokers were replaced by $\frac{5}{8}$-inch chokers.

The basic information pertaining to the re-log smallwood material is presented in Table 6. By comparing this with similar information for the pre-log smallwood and for the largewood materials (see Table 6) it is obvious that the re-log smallwood was by far the smallest material and the most costly to recover on a per unit volume basis. In addition, its dollar value must be considered. Because of its small size, shorter length, and often poorer quality, it could not command the price of standard logs.

FIGURE 11—Re-log smallwood material at the landing.

The time breakdown of the re-log smallwood yarding operation as shown in Table 13 further emphasizes the adverse effect of these small logs.

TABLE 13. RE-LOG SMALLWOOD YARDING

Breakdown of Total Time Based on Crew Minutes and Net Cubic Volume

Phase of Operation	Average Time per C cu.ft./min.		Per Cent of Total Time	
	S1	S2	S1	S2
Haul back	1.9	1.8	8.7	7.1
Stop chokers	1.0	0.8	4.8	3.4
Hook-up	6.6	7.0	30.4	27.8
Haul	4.5	4.3	20.8	17.2
Unhook chokers	1.9	2.2	8.7	8.9
Hang-ups	0.1	0.7	0.7	2.7
Landing delays	—	1.6	0.1	6.5
Other delays	5.6	6.6	25.8	26.4
TOTALS	21.6	25.0	100.0	100.0

To produce 100 cubic feet in the re-log smallwood yarding on S2 required 25.09 crew-minutes, whereas to produce the same volume in the pre-log smallwood yarding on the adjoining quarter, P2, required only 14.12 crew-minutes. This was a direct result of the higher average log volume, and therefore the higher average turn volume in the P2 pre-log smallwood yarding.

The distribution of the turns for the re-log smallwood yarding is shown in Table 14 as a percentage of the total number of turns, of total time, and of total volume recovered.

TABLE 14. TURN DISTRIBUTION—RE-LOG SMALLWOOD MATERIAL

Shown as a Percentage of Total Turns, Total Time, and Total Volume by Turn Volume Classes

Turn Volume Class (cubic feet)	Per Cent of Total No. of Turns	Per Cent of Total Time	Per Cent of Total Volume
20.0 and under	25.2	23.3	11.1
20.1 - 40.0	51.3	51.8	42.8
40.1 - 60.0	11.3	12.0	17.1
60.1 - 80.0	8.7	9.0	17.8
80.1 and over	3.5	3.9	11.2

The information presented in this table further emphasizes the effect of the small volume turns peculiar to re-log yarding operations (1). Turns containing 20 cubic feet or less accounted for 25.2 per cent of the total number of turns, 23.3 per cent of the total time, and only 11.1 per cent of the total volume. Turns containing over 80 cubic feet accounted for only 3.5 per cent of the total number, only 3.9 per cent of the total time, and 11.2 per cent of the total volume.

Loading—Additional time and costs were involved in loading this small material. Because of the predominance of short length small logs, normal loading on conventional logging trucks was not possible; the small material was, instead, bundled and strapped before loading. Each bundle contained approximately 8 to 20 logs depending upon the log size. The bundling and strapping involved extra handling by the loading crew and was a costly operation.

FIGURE 12—A bundle of re-log smallwood is removed from the cradle.

Since it was the policy of the co-operating company to re-log the majority of the settings, they had developed a cradle especially designed for bundling small material. After the logs had been yarded, the loading crew placed them in the cradle and prepared the bundles. By bundling the long logs separately it was possible to obtain enough long bundles to form the base of the load on the conventional logging trucks. The remainder of the load was made up of bundles of short logs.

Because of the time involved in bundling and strapping, the loading crew was unable to load the logs as fast as they were yarded. Consequently more hours were required to load than to yard the same volume. On this basis, the extra time involved made loading a particularly costly factor.

Considering the adverse effect of all these factors, it is unlikely that re-logging by the high-lead method can be considered as anything but a sub-marginal operation. Only in isolated cases, where low-cost specialized equipment can be used to "high grade" re-log material adjacent to existing roads, can it be considered as an economic operation in itself.

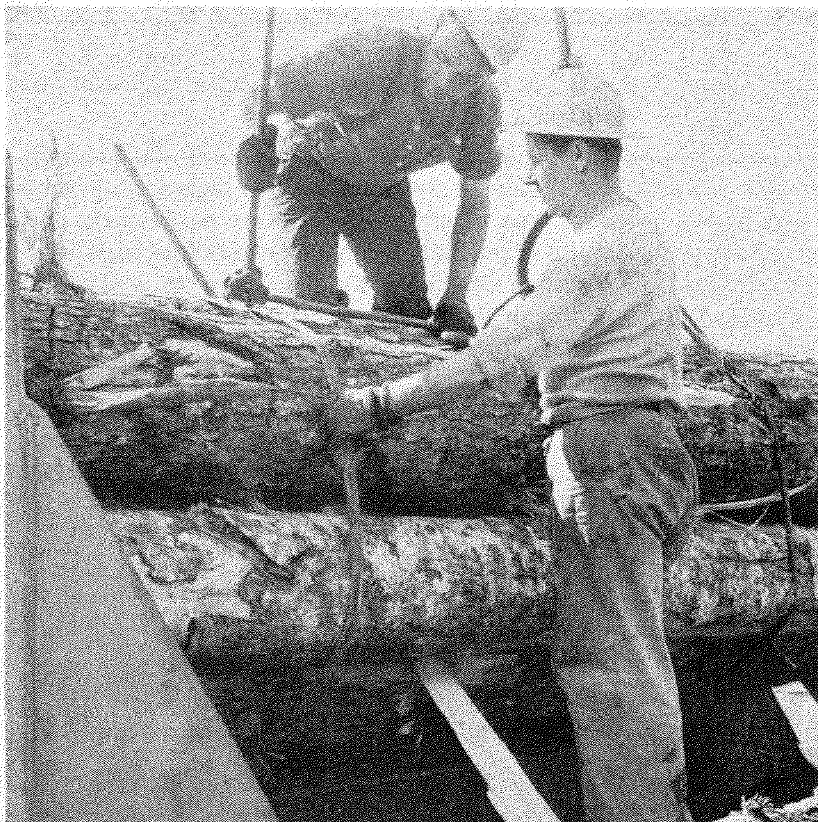

FIGURE 13—Bundling and strapping adds to the cost of handling the re-log smallwood material.

LOGGING RESIDUES

An integral part of this study was the determination of the quality and quantity of residues remaining as waste from each logging method.

After all yarding had been completed, representative sample plots were laid out in each quarter. All pieces 3 inches and over in diameter and 4 feet and over in length, regardless of present economic value, were measured for their sound wood content. This material was segregated by species, volume and diameter classes.

The amount of residue remaining on each quarter is shown in Table 15 as a percentage of the gross volume of the original stand.

TABLE 15. LOGGING RESIDUE SHOWN AS A PER CENT OF GROSS STAND VOLUME

Pre-logged Area (%)			Re-logged Area (%)		
Quarter P1	Quarter P2	Combined P1 and P2	Quarter S1	Quarter S2	Combined S1 and S2
6.3	5.3	5.9	8.1	10.0	9.0

Again the pre-log method showed to advantage. Only 5.9 per cent of the gross volume remained as residue or waste on the pre-logged area compared to 9.0 per cent on the re-logged area. These percentages are particularly noteworthy when compared to the results of past studies made on standard high-lead logging operations. In 1932, Jenkins and Guernsey (5) found 19.2 per cent and, in 1947, Nixon (6) found 25.4 per cent of the gross volume remained as residue or waste on high-lead operations on the British Columbia coast.

FIGURE 14—Logging residue, 1947.

The residue volumes are shown by species on a per acre basis in Table 16 as the number of pieces, the average piece volume, and the total volume per acre for each quarter.

TABLE 16. LOGGING RESIDUE PER ACRE

—	Pulp Species Hemlock and Balsam			Cedar			Total		
	Pieces	Cubic Volume		Pieces	Cubic Volume		Pieces	Cubic Volume	
		Av. Piece	Total		Av. Piece	Total		Av. Piece	Total
Pre-logged Areas									
P1	160	4.1	662	51	8.6	438	211	5.2	1100
P2	82	6.1	497	63	7.0	439	145	6.4	936
Combined P1 and P2	123	4.7	584	57	7.7	438	180	5.7	1022
Re-logged Areas									
S1	189	4.6	866	64	8.2	527	254	5.5	1394
S2	173	4.5	777	106	12.5	1317	279	7.5	2094
Combined S1 and S2	182	4.5	826	83	10.6	883	265	6.4	1709

FIGURE 15—Logging residue, 1960. (Nanaimo Lakes Operation, Crown-Zellerbach Canada, Limited.)

Residue per acre remaining on the pre-logged areas was 40.2 per cent less than on the re-logged areas. The pre-logged area showed to advantage in all categories except the volume of the average piece of the pulp species. Not only were the number of pieces less for each species, but the volume for each species was considerably less on the pre-logged than on the re-logged area.

The large volume of cedar residue on Quarter S2 resulted from severe felling breakage in a very few of the larger cedar trees.

Bucked logs overlooked in yarding accounted for 7.6 per cent of the total residue volume on the whole setting. More logs were overlooked on the re-log than on the pre-log area. The majority of these logs on the re-logged area had been bucked by the salvage buckers but, because of their small size, were overlooked during the re-log smallwood yarding—81.5 per cent of the logs overlooked were less than 8 inches in diameter and 16 feet in length.

The species breakdown of the residues on two adjoining quarters, P2 and S2, is shown in Table 17 as a percentage of total pieces and total cubic volume by top diameter classes.

TABLE 17. LOGGING RESIDUES SHOWN AS A PERCENTAGE OF TOTAL RESIDUE PIECES AND TOTAL RESIDUE VOLUME

Diameter Class (inches)	P2—Pre-log Area				S2—Re-log Area			
	Hemlock and Balsam		Cedar		Hemlock and Balsam		Cedar	
	Pieces	Volume	Pieces	Volume	Pieces	Volume	Pieces	Volume
3	9.0	3.0	—	—	15.1	2.4	1.2	0.2
4	4.1	3.4	4.8	2.4	11.9	3.4	2.0	0.3
5	16.6	9.0	6.9	2.4	5.9	2.7	3.6	1.1
6	3.5	2.4	4.1	2.4	7.1	2.8	5.2	3.4
7	6.2	3.6	4.8	2.8	7.1	6.5	1.6	1.4
8	0.7	0.3	4.8	4.6	4.3	3.8	2.0	1.6
9	4.1	5.2	3.5	4.0	3.2	2.5	3.6	3.4
10	2.8	2.3	4.1	6.0	2.0	1.6	2.4	1.8
11 and 12	4.8	7.8	4.1	5.9	2.0	2.6	4.7	5.4
13 and 14	2.8	5.2	2.1	4.0	2.0	2.2	3.2	6.4
15 and 16	—	—	1.4	1.9	1.2	5.2	2.0	7.6
17 and Over	2.1	10.9	2.7	10.5	0.4	1.7	6.3	30.0

It will be seen from this table that although the smaller pieces accounted for a large percentage of the number of pieces, they constituted only a small percentage of the volume—on Quarter S2 approximately 40 per cent of the pieces were less than 6 inches in diameter, yet made up only 10 per cent of the residue volume. On this same quarter, 30 per cent of the total residue was contained in cedar pieces over 17 inches in diameter. These pieces (6.3 per cent of the total pieces) were from the few cedar trees which suffered severe felling breakage.

COSTS

Cost per unit volume is the most important factor considered by the logging operator. He cannot adopt any new logging method unless, in the final analysis, it proves to be economically sound.

One of the objectives of this study was to compare some of the costs of the two methods, pre-logging and re-logging. The analysis of the cost data indicates that pre-logging was the preferred method.

Only wage costs are considered in this report. Because the same yarding and loading equipment was used in all phases of the study there was little difference in equipment costs between methods, and these costs, together with overhead costs, are not considered. The wage costs are based on the IWA Wage Contract for 1959-60. The largewood material on both areas was felled by contract fallers and these felling costs are based on the contract price adjusted to the rate of production. Power saw costs are not included.

The yarding and loading crew on all but the pre-log smallwood yarding was composed of eight men—a five-man yarding crew and a three-man loading crew. The comparable crew on the pre-log smallwood yarding varied from seven to ten men. In all cases the wage costs are calculated on the total man-hours worked.

The breakdown of the wage costs and net volumes removed on each area, together with the total wage cost per 100 cubic feet for each area, are shown in Table 18. These costs are based on the total net volume removed from the areas.

Total wage costs per 100 cubic feet for the pre-log and re-log methods were $3.92 and $4.58 respectively. This represents a saving of $0.66 per 100 cubic feet by the pre-log method.

DISCUSSION

When evaluating a new logging method, the operator must determine whether or not the new method will have some economic advantage over the old. This economic advantage may be gained either indirectly through a higher degree of utilization which could reduce the overall cost per unit volume, or directly through a saving in wage or machine costs. The results of this study indicate that both indirect and direct savings can be realized with the pre-log method.

1. Utilization

The summary of the analysis of the harvesting losses as presented in Table 19 shows that 3.7 per cent more of the gross stand volume was recovered by the pre-log method. However, based on the actual volume recovered, which is the important factor from the operator's viewpoint, 5.7 per cent *more volume per acre was recovered by the pre-log method.* This fact indirectly affects road construction costs. If more volume be obtained per unit area, it naturally follows that less road construction will be necessary to obtain a required annual production.

As would be expected, the method attaining the higher degree of recovery also proved to be the method showing the lower volume of logging residues. Only 1,022 cubic feet per acre (or 40.2 per cent less material) remained as residue on the pre-logged than on the re-logged area.

TABLE 18. A SUMMARY OF RECOVERED VOLUME AND WAGE COSTS

Pre-log Area

—	Pre-log Smallwood			Pre-log Largewood			Total		
	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.
		$	$		$	$		$	$
Felling and Bucking....	33,001	343.52	1.04	76,599	643.43	0.84	109,600	986.95	0.90
Yarding...............	33,001	1132.20	3.43	76,599	1137.58	1.48	109,600	2269.78	2.07
Loading..............	33,001	496.40	1.50	76,599	546.04	0.71	109,600	1042.44	0.95

Total Wage Costs per 100 cubic feet = $3.92

Re-log Area

—	Re-log Smallwood			Re-log Largewood			Total		
	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.	Volume Recovered (cu.ft.)	Total Wage Cost	Wage Cost per 100 cu.ft.
		$	$		$	$		$	$
Felling and Bucking....	10,980	162.72	1.48	98,597	1045.13	1.06	109,577	1207.85	1.10
Yarding...............	10,980	642.98	5.86	98,597	1879.48	1.91	109,577	2522.46	2.30
Loading..............	10,980	347.48	3.16	98,597	943.16	0.96	109,577	1290.64	1.18

Total Wage Costs per 100 cubic feet = $4.58

TABLE 19. LOGGING LOSSES SHOWN AS A PERCENTAGE OF GROSS VOLUME PER ACRE

Volume	Pre-log Area (%)	Re-log Area (%)
Defect volume	8.3	8.9
Felling and Bucking losses	16.7	17.5
Yarding losses	5.9	8.2
Net volume at landing	69.1	65.4
TOTAL	100.0	100.0

The felling and bucking and yarding losses shown in Table 19 correspond very closely with those found by Nixon (2) for a similar stand in the same general area.

As mentioned previously, the losses presented in this report are based on the gross tree volume rather than the net water or official government scale. On the basis of the net volume loaded at the landing, which corresponds closely with the net water scale, the losses become appreciably higher than those shown in Table 19, and result in only 59.5 and 47.0 per cent of the available volume being recovered on the pre-log and re-log areas respectively.

2. Economics

The greater average log size is the most important factor contributing to the direct saving of $0.66 per 100 cubic feet by the pre-log method. Other factors being equal, the operation handling the larger logs will operate more efficiently. The pre-log method permits some control over the average log volume from the smaller trees and, since these trees under any circumstances produce small and consequently high-cost logs, any method designed to increase the average log size from these trees warrants consideration. While on the re-log area the average log volume of the largewood material was 91.3 cubic feet and of the smallwood material 16.2 cubic feet, in the almost identical stand on the adjacent area, the pre-log method raised these volumes to 126.2 cubic feet for the largewood and 35.6 cubic feet for the smallwood material.

Average log volume directly affects average turn volume. On this setting, the average turn volume was raised from 140 and 32 cubic feet on the re-log large and smallwood respectively, to 180 and 61 cubic feet on the pre-log large and smallwood respectively. The effect of this increased turn volume is evidenced in the total number of turns involved with each method. On the re-logged area, 109,577 cubic feet were removed in 1037 turns, whereas on the pre-logged area, 109,600 cubic feet were removed in 973 turns. In other words, 6.2 per cent fewer turns were required with the pre-log method to harvest the same volume.

The relationship between turn volume and the percentage of total number of turns for each yarding operation on the two adjacent quarters, P2 and S2, is illustrated graphically in Figure 16. From this turn distribution it is readily apparent why the re-log smallwood is such costly material to harvest. Over 50 per cent of the re-log smallwood turns were in the 30 cubic foot class, whereas only 17.5 per cent of the pre-log smallwood turns were in the same costly volume class.

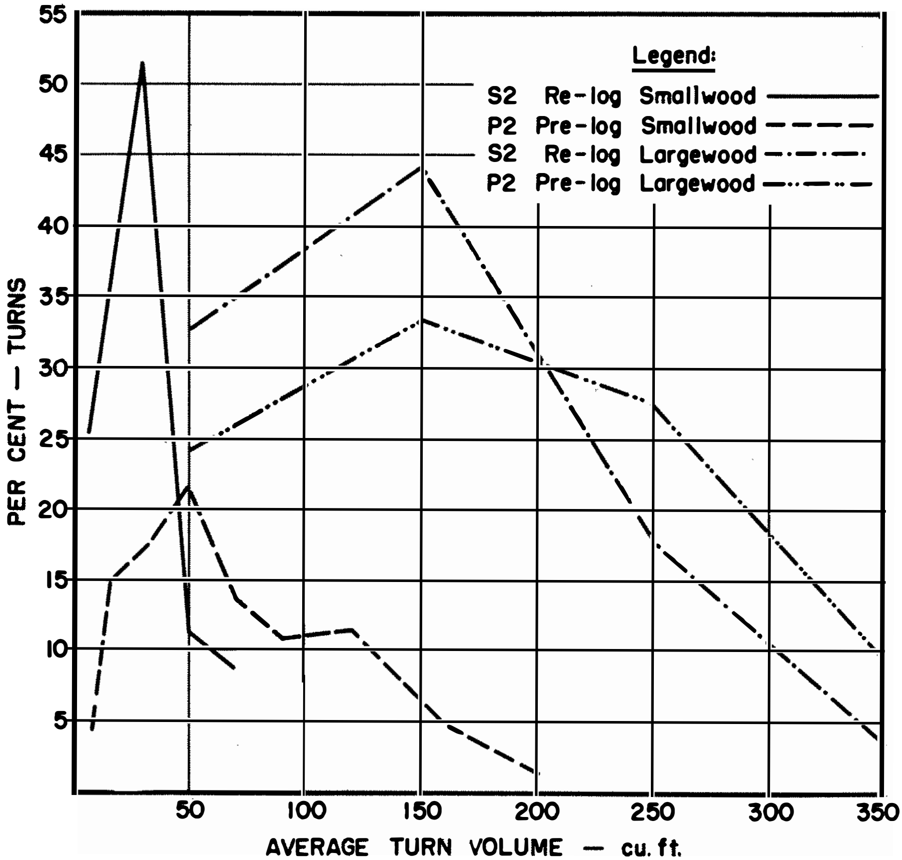

FIGURE 16—Percentage of total number of turns as related to Turn Volume Classes.

A similar situation existed in the largewood turns from both areas. Approximately 45 per cent of the re-log largewood turns occurred in the 150 cubic foot volume class, compared to 33 per cent for the pre-log largewood; whereas approximately 27 per cent of the pre-log and 17 per cent of the re-log largewood turns were in the less costly 250 cubic foot volume class.

Although the results of this experiment clearly indicate that pre-logging was the preferred method on the study area, it is emphasized again that these results apply to this one setting only and are, therefore, indicative up to a point of what might be expected only on other similar operations. The decision to pre-log, to re-log, or clean-log in one operation, depends on many factors too numerous to mention in this publication. Nevertheless, the following are some of the factors which should be taken into account before pre-logging is attempted:

(1) The stand should be uneven-aged or multi-storied.

(2) Enough volume or value must be available in the understory to warrant pre-logging.

(3) The stand must be heavy enough to warrant two logging operations.

(4) Because the stand will be opened up and therefore subject to windthrow, pre-logging should not be carried out too far in advance of the largewood yarding.

(5) A pre-logging program would require that roads be built sooner than would be necessary with a clean-log or re-log program.

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