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Lumber Recovery From Incense-Cedar in Central California

W.Y. Pong and James M. Cahill

THE TREE—The range of incense-cedar extends from the southern slopes of Mount Hood in Oregon south through the Cascade Range, Siskiyou Mountains, Coast Range, and Sierra Nevada to the Sierra San Pedro Martir in Baja California. It grows at increasingly higher elevations toward the southern part of its range. Incense-cedar seldom grows in pure stands; it is generally intermingled with ponderosa pine, sugar pine, Douglas-fir, and white fir. Incense-cedar trees are long lived; large trees are often more than 500 years old. Mature trees have thick, fibrous, light brown or reddish bark that becomes deeply furrowed (see cover). Under average conditions, mature trees are 20-30 inches in diameter and 75-110 feet tall.

THE WOOD—The wood of incense-cedar is nonresinous. Sapwood is white or cream colored, and the heartwood is light brown or reddish brown. Annual rings are moderately distinct and usually measure 20-30 per inch in average material. Incense-cedar wood is exceptionally resistant to decay and highly durable when exposed to weather. It also has high dimensional stability; volumetric shrinkage is only 3.8 percent when the wood is dried from a green state down to 12-15 percent moisture content. Incense-cedar wood is noted for its ease of machining to a smooth, even finish. Because it adheres well under virtually every gluing condition, it is commonly used for pencil stock. Incense-cedar wood weighs about 24 pounds per cubic foot at 12 percent moisture content and has a specific gravity of 0.37.

Natural range of incense-cedar.

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Abstract

Pong W.Y.; Cahill, James M. 1988. Lumber recovery from incense-cedar in central California. Res Pap. PNW-RP-393. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

A sample of 130 incense-cedar (*Libocedrus decurrens* Torr.) trees was selected from the Eldorado National Forest in California. The trees were felled and bucked into 403 woods-length logs and processed through a sawmill cutting Shop and Common grades of lumber. Recovery estimates are shown for woods-length logs based on Scribner board-foot scale and cubic-foot scale. Analysis showed that board-foot recovery ranged from 169 percent for 6-inch logs to 103 percent for 34-inch logs. Cubic-volume recovery of rough green lumber increased from 50 percent to 62 percent for the same range of diameters. Yields of higher quality lumber (Shops and Moulding) increased as log diameter increased. Percentage of Scribner scaled defect was found to be correlated with several measures of product recovery.

Keywords: Lumber recovery, lumber value, incense-cedar, log scale, California.

Summary

This report presents lumber-recovery data for 130 incense-cedar trees selected from the Sierra Nevada of central California. Over 400 woods-length logs were processed through a sawmill cutting Shop and Common grades of lumber. Diameter of the study logs ranged from 6 to 34 inches. The average defect was from 4 to 17 percent Scribner and 3 to 10 percent cubic scale. Lumber recovery is presented on the basis of both board feet and cubic feet.

Several measures of product recovery were correlated with scaling diameter. Regression models were developed for the following variables:

- Board-foot recovery percent;
- Cubic recovery percent of lumber, sawdust, and chips;
- Board foot of lumber per cubic foot of lumber;
- Percent lumber-grade recovery; and
- Dollars per thousand board feet lumber tally ($/MLT).

Board-foot recovery percent decreased as log diameter increased; values ranged from 169 percent for 6-inch logs to 103 percent for 34-inch logs. Cubic lumber-recovery percent increased rapidly in the smaller logs (6-14 inches), leveled off in the midsize logs (16-24 inches), and decreased slightly for logs over 24 inches. Board foot of lumber per cubic foot of lumber decreased with increasing log size because 6/4-inch lumber items were cut oversized to allow remanufacture into alternate products. Larger logs produced a greater proportion of 6/4 lumber. The average lumber value ($/MLT) increased with increasing log diameter because of the production of highly valued lumber items (Shops and Moulding) from the larger logs. Lumber values are based on 1985 prices; two methods that allow users to update the $/MLT to future prices are presented.

The percentage of Scribner scaling defect was correlated with board-foot recovery percent and $/MLT. As defect percent increased, board-foot recovery percent increased and $/MLT decreased.

Log values were computed indirectly from previously defined recovery ratios. Dollars per thousand board feet of net log scale decreased for logs up to 14 inches and then increased. Dollars per hundred cubic feet of cubic product scale increased with increasing log size.

Factors for converting Scribner log scale to cubic log scale were computed for gross and net scales. Conversion factors were correlated with scaling diameter; the ratio of board feet to cubic feet increased as log size increased.

Contents

Introduction

Incense-cedar (*Libocedrus decurrens* Torr.) is an important commercial softwood species in the Western United States. Currently about 14 billion board feet of commercial-size incense-cedar are growing in the West with the majority of volume (72 percent) in California (USDA Forest Service 1973b). Incense-cedar wood is manufactured into many products including lumber, pencil stock, fence posts, and shakes.

The major objective of this study was to determine the volume and value of lumber from incense-cedar trees. This research provides managers of both public and private timberlands with the basic data they need to estimate the lumber volume and grade recovery from this species. Results of the study can also be used by loggers, sawmill operators, timber growers, and forest administrators for other activities including log allocation, mill design, and equipment evaluation.

This study was a cooperative effort by the Pacific Northwest Research Station (PNW), the Pacific Southwest Region of the National Forest System, and the Wetsel-Oviatt Lumber Company of Shingle Springs, California.

The data summarized in this publication are available from PNW on a 5-1/4-inch diskette. Readers can receive this information by sending a double-sided, double density diskette to the Pacific Northwest Research Station, Timber Quality Project, P.O. Box 3890, Portland, OR 97208-3890. A listing of the data format is shown in appendix 1.

Methods

Sample Selection

A total of 130 incense-cedar trees were selected from six areas in the Eldorado National Forest (fig. 1). Trees were selected to represent the range of size and quality in incense-cedar. Sample trees ranged from 10 to 54 inches in diameter at breast height (DBH).[1] Tree quality was based on Pacific Southwest Region Dinuba Grades (Wise and May 1958) as applied to the first 16-foot log in the tree. Table 1 shows the distribution of sample trees by tree DBH, tree height classes, and the Dinuba Grades.

We should emphasize that the sample reflected the range of size and quality existing in incense-cedar and provides a base for predicting the volume and value of similar trees or logs. The sample was not selected to produce the mix of log sizes and grades normally found in a mill.

Harvesting and Scaling

Trees were felled and bucked in accordance with normal industry practices. Each log was identified by tree number and position of the log within the tree. This number was used to identify lumber items sawn from a specific log. Study logs were trucked to the cooperating mill where they were scaled. Scribner scale was taken by USDA Forest Service check scalers according to the National Forest Log Scaling Handbook (USDA Forest Service 1973a).[2] Cubic scale was taken in conformance with the draft of the proposed cubic scaling handbook.[3] The number of logs and the average percentage of Scribner and cubic scaling defect is shown by Scribner scaling diameter in table 2.

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[1] Diameter of the tree at 4-1/2 feet above the ground as measured on the uphill side of the tree.

[2] The rules for scaling pecky rot were modified in this study. Pockets of rot were squared out and deducted only if they were less than 4-1/2 inches apart; all other pockets were ignored.

[3] USDA Forest Service cubic scaling handbook (review draft). 1978. Washington, DC: U.S. Department of Agriculture, Forest Service. 192 p.

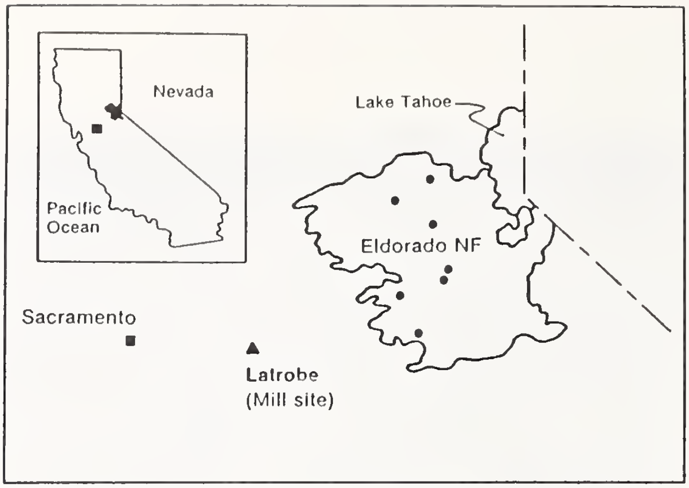

Figure 1—Approximate locations where trees were selected in the Eldorado National Forest, California, and the mill location.

Table 1—Number of incense-cedar trees by DBH class, height range, and butt-log grade

DBH class	Height range[a]	Butt-log grade[b] 1	2	3/4[c]	9[d]	Total
Inches	*Feet*	*Number of Trees*				
10.6-15.5	27- 56	0	0	10	0	10
15.6-20.5	39- 67	1	4	15	0	20
20.6-25.5	49- 94	0	4	11	2	17
25.6-30.5	60-112	2	8	3	4	17
30.6-35.5	70-130	3	10	1	0	14
35.6-40.5	67-130	8	10	0	2	20
40.6-45.5	54-125	4	5	0	4	13
45.6-50.5	101-144	8	4	0	2	14
50.6-55.5	112-142	4	1	0	0	5
Total		30	46	40	14	130

[a] Tree height above a 1-foot stump.
[b] Pacific Southwest Region Dinuba grades applied to 16-foot butt log (Wise and May 1958).
[c] Trees with these butt-log grades were combined into one grade group.
[d] Trees with cull butt logs but with merchantable upper logs.

Table 2—Number of woods-length incense-cedar logs, by scaling diameter and the average percent Scribner and cubic log-scale defect

Scaling diameter	Number of logs	Defect Scribner	Cubic
Inches		*Percent*	
6- 8	83	4.0	3.0
9-10	32	10.7	4.0
11-12	47	7.8	4.1
13-14	34	7.3	3.2
15-16	42	7.1	6.2
17-18	26	9.9	5.3
19-20	33	11.4	3.8
21-22	35	11.6	7.8
23-24	20	12.2	4.3
25-26	10	11.5	9.5
27-28	21	12.0	6.5
29-30	9	17.0	5.8
31-32	5	9.5	4.3
33-34	6	13.0	8.8
Total or average	403	8.7	4.8

Gross cubic-foot volume of butt logs was estimated using an equation developed by Bruce (1982):

$$\text{Cubic-foot volume} = 0.005454L\,(0.75\,SD^2 + 0.25\,LD^2)\ .$$

Smalian's formula was used to compute gross cubic-foot volume for all other logs:

$$\text{Cubic foot volume} = 0.005454L\,\frac{(SD^2 + LD^2)}{2}\ ,$$

where L is log length in feet,
SD is the small-end diameter in inches,
LD is the large-end diameter in inches, and
0.005454 is a conversion constant.

Cubic product scale is defined as the gross cubic-foot volume reduced for all defects expected to affect the yield of solid-wood products.

Processing

Study logs were sawn by the Wetsel-Oviatt Lumber Company mill near Latrobe, California. Milling conformed to the general industry practice of sawing each log for maximum lumber volume consistent with the recovery of the highest lumber-grade yield. Production equipment in the sawmill included a ring debarker, single-cut band headsaw, single-band vertical resaw, double arbor edger, and a trim saw. Lumber is sorted from the green chain with an edge-drop sorter, and stickered or stacked, or both, with two mobile stickering machines.

All lumber met the standards of the national grading rules for softwood lumber and appropriate regional rules as published by the Western Wood Products Association (WWPA 1981). Grading of all lumber items was supervised by a WWPA grade inspector. The mill normally kiln dries incense-cedar Shops, and Moulding and Selects, but not the Commons. Not all lumber was graded in the same condition: Moulding and Selects were graded rough dry, Shops were graded surfaced two sides, and Commons were graded rough green. Lumber dimensions, grade, and tree-log identification number of each lumber item were tallied after grading. Eleven grades of lumber were produced during the study; for ease of presentation, they were combined into five grade groups:

Grade group	Lumber grades
Moulding and Better (Mldg & Btr)	Selects Moulding
Shops	Factory Select/3 clear 1,2,3 Shop Shop outs
3 and Better Common (3 & Btr Com)	1,2,3 Common
4 Common	4 Common
5 Common	5 Common

Analysis

The purpose of the analysis was to develop, for woods-length logs, regression equations predicting:

1. The volume yield of primary (lumber) and secondary products (sawdust and chips).
2. Grade recovery of lumber.
3. Lumber and log values.

Independent Variables

Log diameter—Scribner scaling diameter (D) and transformations of D were used as independent variables to find the best equation for each dependent variable. Inverse polynomial curves, which were found useful in modeling lumber recovery data in other studies (Snellgrove and Cahill 1980), were applied. A final curve for each dependent variable was selected based on the model with the highest coefficient of determination (R^2).

Defect—When possible, regression models were developed by using the percentage of log defect as an additional independent variable. Defect percent was computed using Scribner and cubic log-scale estimates of defect volume.

Direct product estimators—Cubic product scale was used as a direct product estimator to predict the cubic-foot volume of lumber, sawdust, and chips (Fahey 1983).

Dependent Variables[4]

Regression models were developed for the following dependent variables:

Product-volume recovery—
1. Board-foot recovery percent.
2. Cubic recovery percent (lumber, sawdust, and chips).
3. The ratio of board feet of lumber to cubic feet of lumber (BF/CF Lum).

Lumber-grade recovery—
The volume of lumber recovered in each lumber-grade group was expressed as a cumulative percentage of the total lumber volume in the log.

Value recovery—
1. Lumber value in dollars per thousand board feet lumber tally ($/MLT).
2. Log value in dollars per thousand board feet of net Scribner log scale ($/MNLS).
3. Log value in dollars per hundred cubic feet of cubic product scale ($/CCF).

Log-scale conversion factors—
1. Ratio of gross Scribner log scale to gross cubic-foot log scale (BF/CF Log Gross).
2. Ratio of net Scribner log scale to cubic product scale (BF/CF Log Net).

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[4] Dependent variables are defined in appendix 2.

Results and Discussion

Volume Recovery

Board-foot recovery percent—Overrun is a common term used to describe the percentage of lumber recovered (board-foot tally) in excess of Scribner net log scale. Recovery percent, often confused with overrun, is the ratio of lumber tally to net log scale expressed as a percentage. A recovery percent of 150 is equivalent to an overrun of 50 percent. We will use board-foot recovery percent.

As expected, board-foot recovery percent decreased as log diameter increased (fig. 2). Recovery values ranged from a high of 169 percent for 6-inch logs to a low of 103 percent for 34-inch logs. This trend occurred because Scribner log scale underestimates the board-foot volume of small-diameter logs. Table 3 presents board-foot recovery percent for incense-cedar logs by 2-inch diameter classes.

The statistical relation between recovery percent and log diameter, although not strong (R^2 = 0.18), was highly significant (P = 0.01). These results suggest that users should estimate recovery percent of incense-cedar by diameter class rather than by using an overall average. The sample of trees selected for this study would not necessarily produce the log-diameter distributions encountered in typical commercial operations. As previously noted, selection was made to represent the size and quality available in incense-cedar from which a statistically valid base for predicting volume and value could be made.

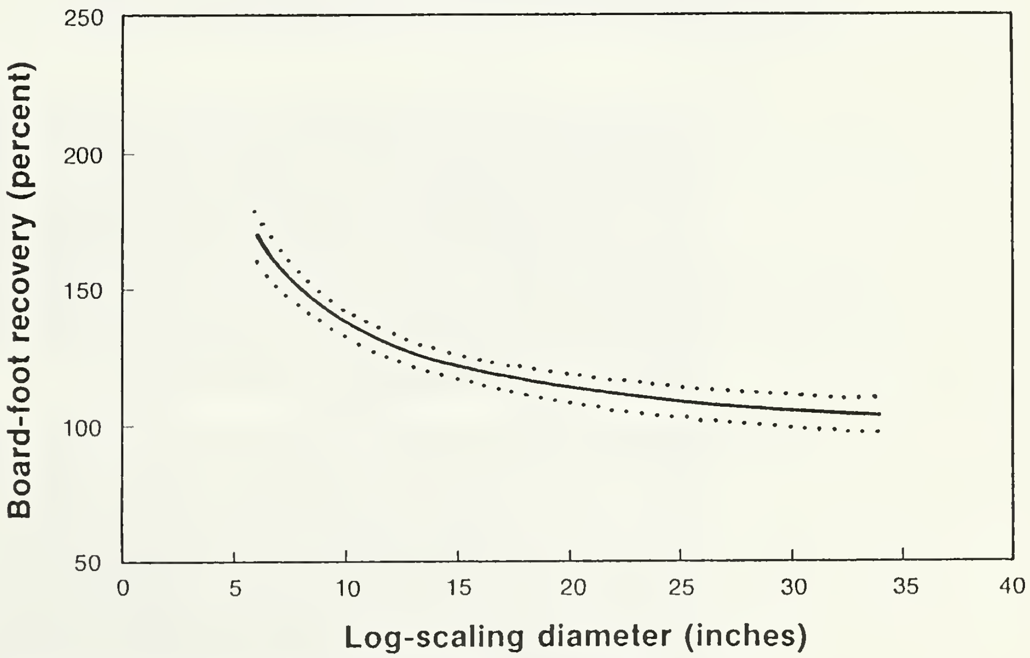

Figure 2—The relation of board-foot lumber-recovery percent (solid line) and the 95-percent confidence intervals (dashed lines) to log-scaling diameter. The regression equation is shown in appendix 3.

Table 3—Board-foot recovery percent by scaling diameter with 95-percent confidence interval (CI)

Scaling diameter	Board-foot recovery[a]	CI[b]
Inches	----- *Percent* -----	
6	169	9
8	149	6
10	137	4
12	129	4
14	123	4
16	119	4
18	116	5
20	113	5
22	111	5
24	109	6
26	107	6
28	106	6
30	105	6
32	104	6
34	103	6

[a] Regression equation listed in appendix 3.
[b] CI is the half-width of the 95-percent confidence interval for expected mean value of the dependent variable, recovery percent.

Table 4—Board-foot recovery percent by scaling diameter and percentage of Scribner scaling defect

Scaling diameter	Scribner scale defect percent					
	0	10	20	30	40	50
Inches	----- *Board-foot recovery percent*[a] -----					
6	164	168	178	195	219	249
8	142	146	156	173	197	227
10	129	133	143	160	184	214
12	121	124	134	151	175	206
14	114	118	128	145	169	199
16	110	113	123	140	164	195
18	106	109	120	137	160	191
20	103	107	117	134	158	188
22	101	104	114	131	155	186
24	99	102	112	129	153	184
26	97	101	111	128	152	182
28	96	99	109	126	150	181
30	94	98	108	125	149	179
32	93	97	107	124	148	178
34	92	96	106	123	147	177

[a] Regression equation listed in appendix 3.

Board-foot recovery percent was also correlated with the percentage of log defect, based on Scribner log scale. R^2 increased from 0.18 to 0.32 when the square of Scribner defect percent was included as an additional independent variable in the model. We found that within a diameter class, recovery percent increased as the percentage of defect increased (table 4). This was most likely due to excessive Scribner log-scale deductions that caused high recovery percents. The primary defect occurring in the study logs was pecky rot caused by the wood-rotting fungus *Polyporous amarus* Hedgc. (fig. 3). In a corollary study, Cahill and others (1987) found that Scribner scale deductions for pecky rot were excessive.

Cubic recovery percent—An accurate representation of the relation of lumber volume to log volume requires that both measures of volume be commensurable. Cubic recovery percent represents such a relation because both lumber and log volumes are accurately measured in cubic feet (Fahey and Snellgrove 1982). Figure 4 shows the percentage of cubic product scale recovered as rough green lumber, sawdust, and chips by log diameter. The curves are cumulative; that is, separate recovery-percent curves were determined, first for rough green lumber and then for rough green lumber plus sawdust. The percentage of product scale available for chips can be estimated by subtracting the cumulative percentage of rough green lumber plus sawdust from 100 percent.

Figure 3—Incense-cedar log ends showing (A) scattered pecky rot typical of the early stages of decay, and (B) large numerous peck holes typical of advanced decay.

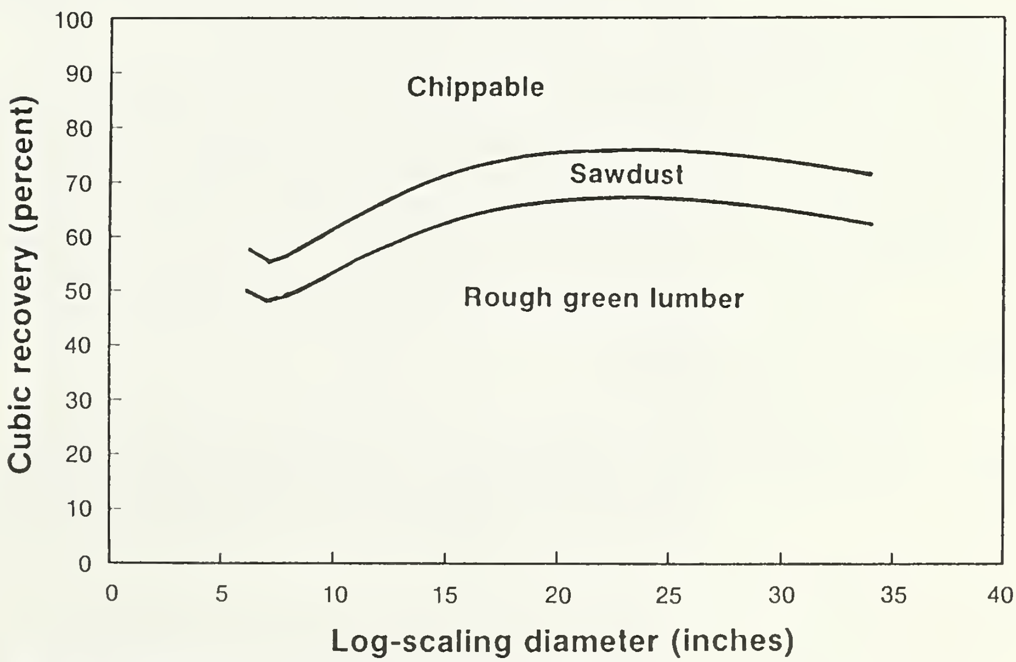

Figure 4—The relation of cubic recovery percent of rough green lumber, sawdust, and chips to log-scaling diameter. Regression equations are shown in appendix 3.

Table 5—Percent of cubic product scale manufactured into rough green lumber, sawdust, and chips, by scaling diameter[a]

Scaling diameter	Rough green lumber	Sawdust[b]	Chips[c]
Inches		*Percent*[d]	
6	50	8	42
8	49	8	43
10	53	8	39
12	57	8	34
14	61	8	31
16	63	9	28
18	65	9	26
20	66	9	25
22	67	9	24
24	67	9	24
26	66	9	24
28	66	9	25
30	65	9	26
32	64	9	27
34	62	9	28

[a] Regression equations listed in appendix 3.
[b] Percentage of sawdust calculated by subtracting the cubic recovery percent of rough green lumber from the cubic recovery percent of rough green lumber and sawdust.
[c] Percentage of chips calculated by subtracting the cubic recovery percent of rough green lumber and sawdust from 100 percent.
[d] Percentages may not total 100 because of rounding.

Table 6—The ratio of board feet of lumber to cubic feet of lumber (BF/CF Lum) by scaling diameter with 95-percent confidence interval (CI)

Scaling diameter	BF/CF Lum[a]	CI[b]
Inches	*Board-foot per cubic foot*	
6	10.49	0.02
8	10.45	.01
10	10.43	.01
12	10.41	.01
14	10.40	.01
16	10.39	.01
18	10.39	.01
20	10.38	.01
22	10.38	.01
24	10.37	.01
26	10.37	.01
28	10.37	.01
30	10.37	.01
32	10.36	.01
34	10.36	.01

[a] Regression equations listed in appendix 3.
[b] CI is the half-width of the 95-percent confidence limit for the expected mean value of the dependent variable, board foot per cubic foot lumber ratio (BF/CF Lum).

Cubic recovery of lumber increased sharply in the smaller diameter logs (6-14 inches), leveled off in the midsize logs (16-24 inches), and then dropped off slightly in the larger logs (26-34 inches). The rapid rise of lumber recovery in the smaller diameter logs reflects the relative inefficiency of converting these logs into lumber. This is particularly evident in the 7- to 8-inch logs; where the cubic recovery was less than that of 6-inch logs (figure 4, table 5), suggesting that the choice of lumber items cut from the 7- to 8-inch logs did not fully use the log. The addition of cubic log-scale defect as an independent variable did not significantly improve the regressions for cubic recovery. Table 5 presents the cubic recovery percentages of lumber, sawdust, and chips by 2-inch log-diameter classes.

BF/CF Lum—The ratio of nominal board-foot volume of lumber per cubic-foot volume of rough green lumber (BF/CF Lum) is an expression frequently used in converting lumber recovery in cubic feet to board feet (Fahey and Woodfin 1976). Regression analysis showed that BF/CF Lum decreased as diameter increased. The decrease was caused by the different amounts of fiber used to produce 1-inch boards versus 6/4 lumber. At the study mill, 6/4 items were cut oversized to allow for possible remanufacture into other products. This tended to bring the average BF/CF Lum down for large logs, where a greater proportion of the lumber produced was in the 6/4 thickness. Table 6 shows the estimated BF/CF Lum by 2-inch log-diameter classes.

One important use of BF/CF Lum is to compute lumber recovery factors (LRF) (Fahey and Snellgrove 1982). LRF is defined as the board-foot volume of lumber produced from a cubic-foot volume of log. It can be estimated for any given log-diameter class by multiplying the cubic lumber-recovery percent by the BF/CF Lum. For example, LRF for a 20-inch log would be calculated as follows:

Cubic recovery percent of rough green lumber (table 5) = 66 percent;
Average BF/CF Lum (table 6) = 10.38 board feet per cubic foot lumber;
LRF = 0.66 x 10.38 = 6.85 board feet lumber per cubic foot log.

This LRF is based on a cubic product scale.

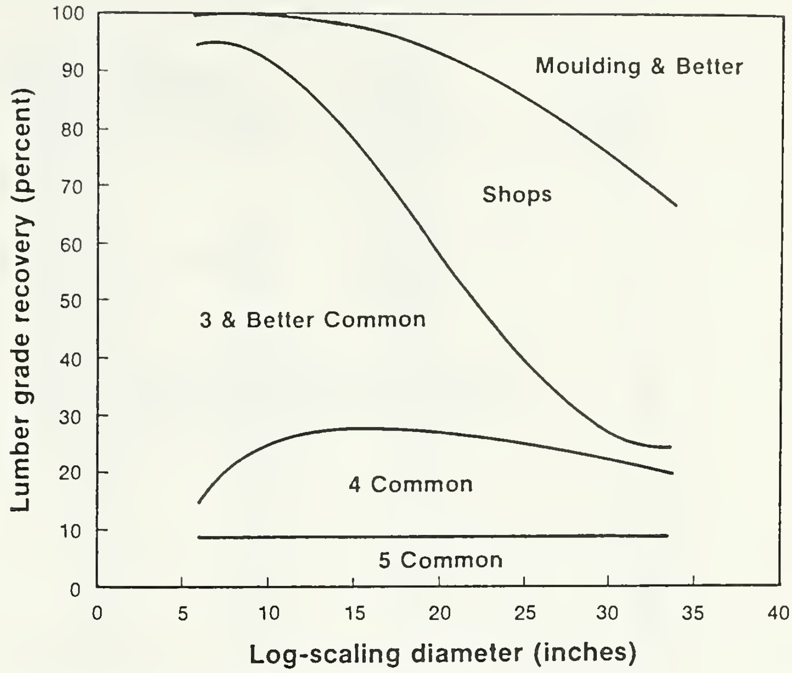

Figure 5—Cumulative percentage of volume by lumber grade. The space between the curves represents the percentage of volume for individual lumber grades. Regression equations are shown in appendix 3.

Lumber-Grade Recovery

Percentage of lumber volume by lumber grade—The cumulative percentage of lumber volume recovered in the five grade groups of lumber (see "Processing" for lumber grades in each group) was correlated with log diameter (fig. 5). As expected, a general trend occurred of increasing recovery of high-quality lumber as log diameter increased. Smaller logs produced a high proportion of Common grade lumber, and larger logs recovered greater volumes in the Shops and Moulding grades. The estimated percentages of lumber volume in each separate lumber-grade group are given in table 7. Users should be aware that these values represent general trends; a large proportion of the variation in grade yields is not accounted for by regression models with log diameter as the only independent variable.

The yield of 5 Common lumber did not vary by log diameter (fig. 5) but did increase as the percentage of Scribner log-scale defect increased (fig. 6). Much of the increase in scale defect was due to the occurrence of pecky rot in the highly defective logs. Grade 5 Common lumber sawn from these logs generally contained numerous scattered pockets of rot (peck holes).

Table 7—Percent of lumber-grade recovery by scaling diameter[a]

Scaling diameter	Lumber grade: 5 Common	4 Common	3 and Better Common	Shops	Moulding and Better
Inches			*Percent*[b]		
6	8	7	80	6	0
8	8	13	73	6	0
10	8	17	67	8	0
12	8	19	61	12	1
14	8	19	54	17	2
16	8	20	47	23	3
18	8	19	39	29	5
20	8	19	32	35	7
22	8	18	25	40	9
24	8	17	18	44	12
26	8	16	12	48	15
28	8	15	8	49	19
30	8	14	5	50	23
32	8	13	4	47	28
34	8	12	5	43	33

[a] Regression equations listed in appendix 3.
[b] Percentages may not total 100 because of rounding.

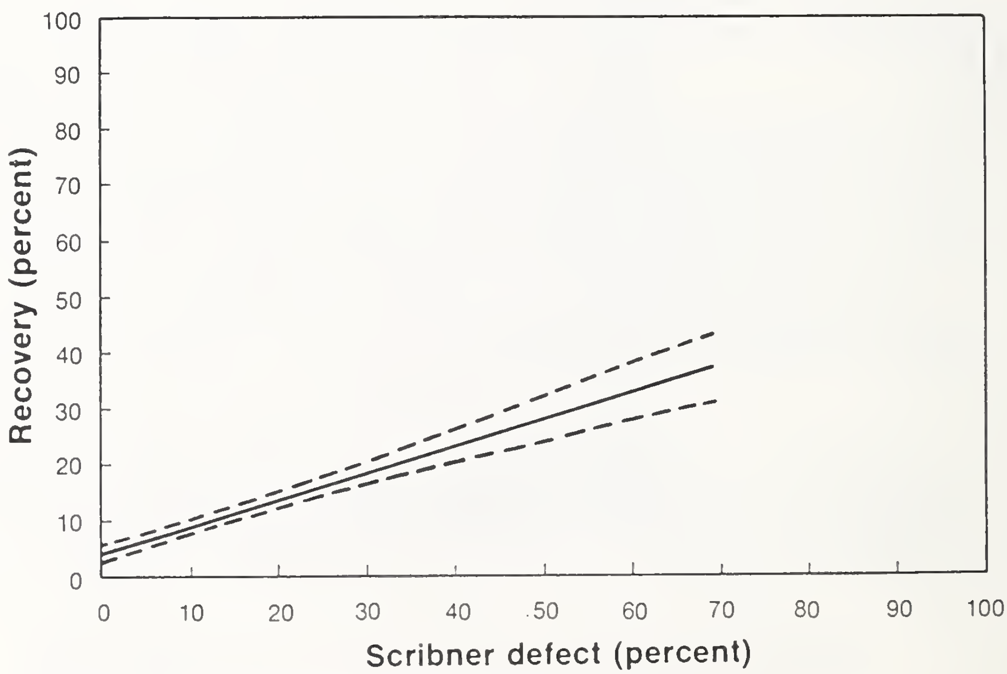

Figure 6—The relation of percent recovery of 5 Common lumber (solid line) and the 95-percent confidence intervals (dashed lines) to the percentage of Scribner scaling defect. The regression equation is shown in appendix 3.

Table 8—Lumber prices used to calculate average lumber value[a]

Lumber grade	Price per thousand board feet
	Dollars
Moulding and Better	756.24
Factory Select/3 Clear	438.25
1 Shop	441.37
2 Shop	347.14
3 Shop	272.75
Shop out	91.17
3 and Better Common	283.65
4 Common	207.79
5 Common	70.29

[a] Lumber prices are the 1985 average regional prices as supplied by USDA Forest Service, Pacific Southwest Region, San Francisco, California.

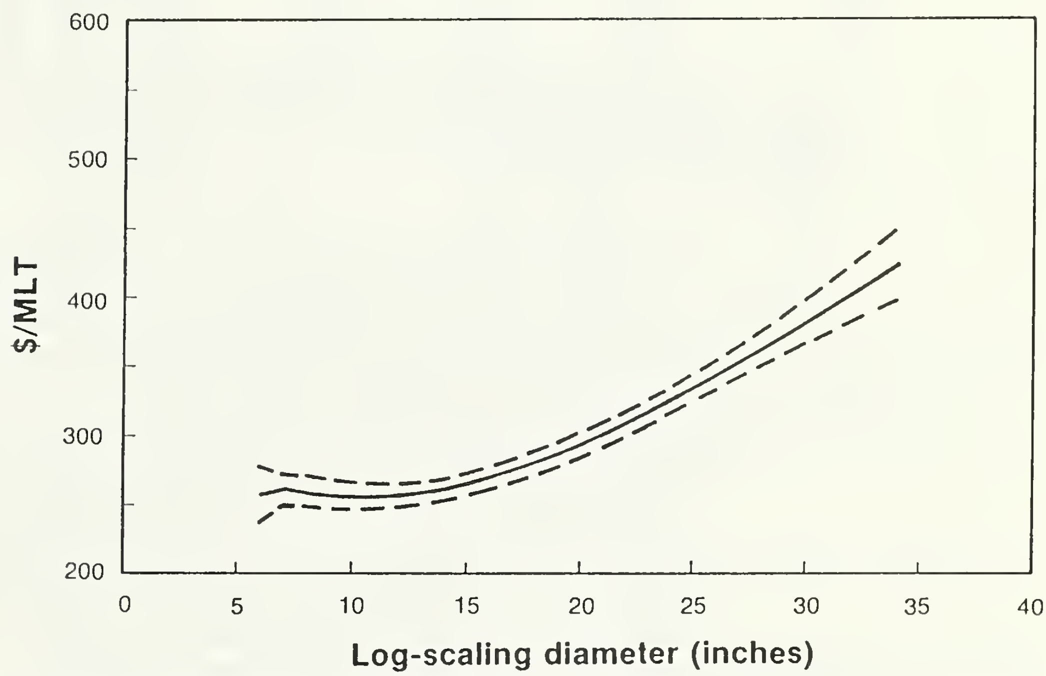

Figure 7—The relation of lumber value ($/MLT) (solid line) and the 95-percent confidence intervals (dashed lines) to scaling diameter. The regression equation is shown in appendix 3.

Value Recovery

**$/MLT**—Lumber value is determined by applying an appropriate price to the volume of each grade of lumber produced from a log. Prices we used are shown in table 8. The total value of the lumber in the log divided by the total lumber volume in thousands of board feet ($/MLT) is a useful index of log quality. Figure 7 shows that the average $/MLT increased as log diameter increased. The average lumber value for 34-inch logs, for example, is 65 percent higher than the average value for 6-inch logs. The value increase is due mainly to the greater proportion of higher value lumber produced from the larger logs. Table 9 shows the estimated $/MLT for the study logs by 2-inch log-diameter classes.

Table 9—Lumber value ($/MLT), based on 1985 prices, by scaling diameter with 95-percent confidence interval (CI)

Scaling diameter	Lumber value ($/MLT)[a]	CI[b]
Inches	*Dollars per thousand board feet*	
6	257	20
8	260	11
10	256	10
12	256	8
14	261	8
16	269	8
18	280	9
20	293	9
22	308	8
24	325	9
26	343	10
28	362	13
30	382	16
32	403	20
34	424	25

[a] Regression equation listed in appendix 3.
[b] CI is the half-width of the 95-percent confidence limit for the expected mean value of the dependent variable, lumber value ($/MLT).

Table 10—Lumber value ($/MLT), based on 1985 prices, by scaling diameter and percentage of Scribner scaling defect

Scaling diameter	Scribner scale defect percent					
	0	10	20	30	40	50
Inches	----- *Dollars per thousand board feet*[a] -----					
6	262	250	238	226	214	202
8	267	255	243	231	219	207
10	265	253	241	229	217	205
12	266	254	242	230	218	206
14	271	259	247	235	223	211
16	280	268	256	244	232	220
18	291	280	268	256	244	232
20	306	294	282	270	258	246
22	322	310	298	286	274	262
24	339	327	315	303	291	279
26	358	346	334	322	310	298
28	377	365	354	342	330	318
30	398	386	374	362	350	338
32	419	407	395	383	371	359
34	441	429	417	405	393	381

[a] Regression equation listed in appendix 3.

The lack of an appropriate log-grading system for incense-cedar precludes analyzing the relation of $/MLT vs. log diameter for individual log grades. Because of this, users should note that the averages listed in table 9 are composite values of $/MLT for all logs processed in the study and represent a wide range of log quality.

Even without a visual-grading system, we found logs can be stratified into quality classes by using the percentage of Scribner scale defect as a surrogate variable for log grade. When included as an additional independent variable in the model predicting $/MLT, defect percent increased the coefficient of determination from 0.28 to 0.36. Within a diameter class, $/MLT decreased as the percentage of defect increased. As shown earlier (fig. 6), production of low-value lumber (5 Common) increased as Scribner defect percent increased. Table 10 presents $/MLT by log diameter and percentage of scaling defect.

Repricing— A problem with $/MLT is that the lumber prices used to compute it represent a fixed point in time. Lumber prices fluctuate with supply and demand; thus the ability to quickly reprice the data and compute a new $/MLT is important. One approach is to use the price of a lumber grade such as 3 and Better Common to adjust the $/MLT by the ratio of new price to old price. As an example, we used a price of $283.65/MLT for 3 and Better Common (table 8). If the price rose to $350.00/MLT, then the $/MLT for each diameter class would be adjusted by the ratio of 350.00/283.65, or 1.23. The one advantage of using this approach is that it is quick; however, it assumes other lumber values will change in the same proportion and direction, and this may or may not be true.

A more accurate method of repricing lumber value is to estimate a new $/MLT weighted by the percentage of lumber volume in each lumber-grade group for each diameter class. As an example, consider a new set of lumber prices:

Grade group	$/MLT
Moulding and Better	$593.64
Shops	278.86
3 and Better Common	410.02
4 Common	207.40
5 Common	112.30

The new $/MLT for 6-inch logs is computed as follows:

5 Common	0.08 × 112.30	=	$ 8.98
4 Common	0.07 × 207.40	=	14.52
3 and Better Common	0.80 × 410.02	=	328.02
Shops	0.06 × 278.86	=	16.73
Moulding and Better	0.00 × 593.64	=	0.00
			$368.25

where 0.08, 0.07, 0.80, 0.06, and 0.00 are the proportions of the lumber volume produced from a 6-inch log in each lumber grade group (table 7);
112.30, 207.40, 410.02, 278.86, and 593.64 are the new lumber prices for these respective lumber grades or grade groups; and
368.25 is the new $/MLT for 6-inch logs.

This procedure can be repeated for each diameter class to produce a new $/MLT curve.

The price for Shops ($278.86) in the above calculations represents an average price weighted by the percentage of the Shop volume in the various Shop grades. The percentages of Shop grades manufactured during this study were as follows:

Shop grade	Percent
Factory Select/3 Clear	0.3
1 Shop	10.9
2 Shop	44.7
3 Shop	41.7
Shop outs	2.4

These proportions were used to calculate a weighted average price for the lumber-grade group "Shops" by using the new prices of the various Shop grades.

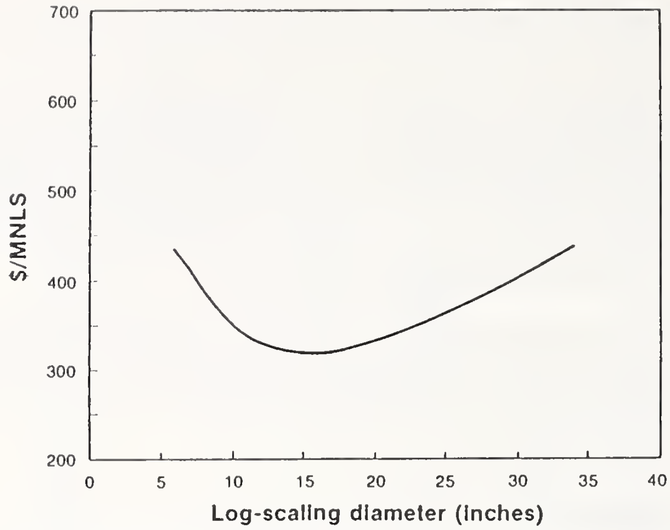

Figure 8—The relation of log value in dollars per thousand net log scale ($/MNLS) to scaling diameter.

$/MNLS—The $/MNLS was estimated for each diameter class by multiplying the board-foot recovery percent (table 3) by the average lumber value (table 9). The relation of $/MNLS to log diameter is shown in figure 8. The $/MNLS decreased for logs 6-14 inches in diameter because board-foot recovery percent decreased. Above 14 inches, the $/MNLS increased because of the recovery of high-valued lumber. Users can update the $/MNLS curve to future prices by updating the $/MLT and recomputing the diameter-class values.

$/CCF—The $/CCF was estimated for each diameter class by multiplying the cubic lumber recovery percent (table 5) by the board feet per cubic foot of lumber (BF/CF Lum, table 6) and the average lumber value ($/MLT, table 9). The values are shown plotted over scaling diameter in figure 9. The $/CCF increased with log size because both cubic recovery percent and the average lumber value increased over diameter. Users can update the $/CCF by updating the $/MLT and recomputing $/CCF.

Direct Product Estimators

Figure 10 shows the linear relation between the cubic volume output of incense-cedar products and the cubic product scale of the logs. Regression equations expressing these relations can be used to estimate the cubic product yield for logs with varying amounts of cubic product scale. Cubic yields of lumber volume estimated with the use of the regression equation can be converted to board feet by multiplying the cubic yields by the appropriate BF/CF Lum from table 6 (discussed earlier).

Log-Scale Conversion Factors

Log-scale conversion factors (BF/CF Log) enable users to convert Scribner log volumes to estimates of cubic-foot volumes. Conversion factors have been developed for several timber species (Cahill 1985, Hartman and others 1975); none are applicable to incense-cedar because of the type and extent of defect and the unusual taper of this species.

Computed values of BF/CF Log for gross and net scale were regressed over log diameter (fig. 11). The trend of increasing BF/CF Log with increasing diameter reflects the low estimates of Scribner board-foot volumes in smaller logs. The BF/CF Log based on net scales were consistently less than those for gross scales because, for a given defect, Scribner scaling rules dictate a greater proportion of log volume be deducted than is dictated by the cubic rules (see table 2). The BF/CF Log for gross and net scales are presented by 2-inch diameter classes in table 11.

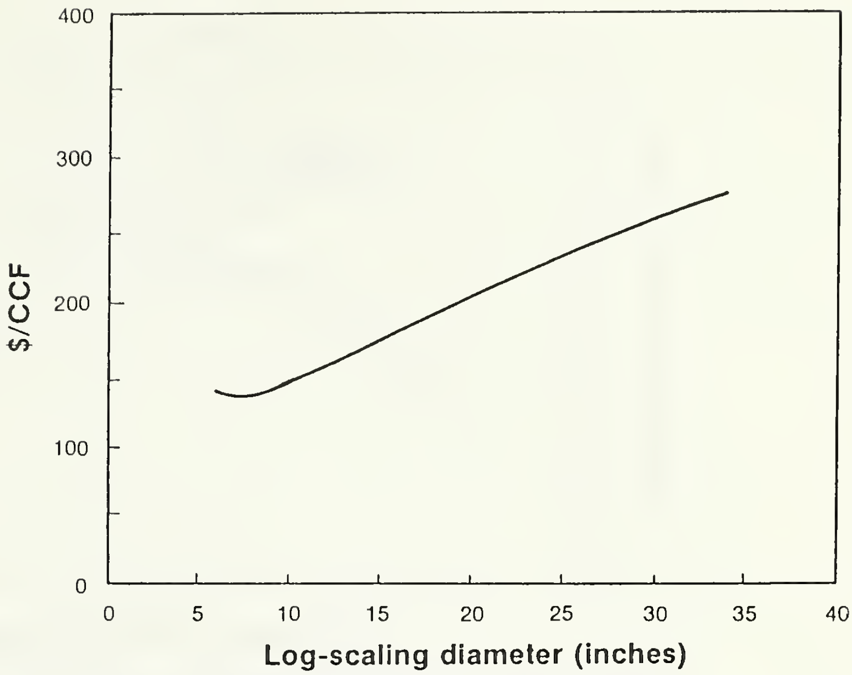

Figure 9—The relation of log value ($/CCF) in dollars per hundred cubic feet of cubic product scale to scaling diameter.

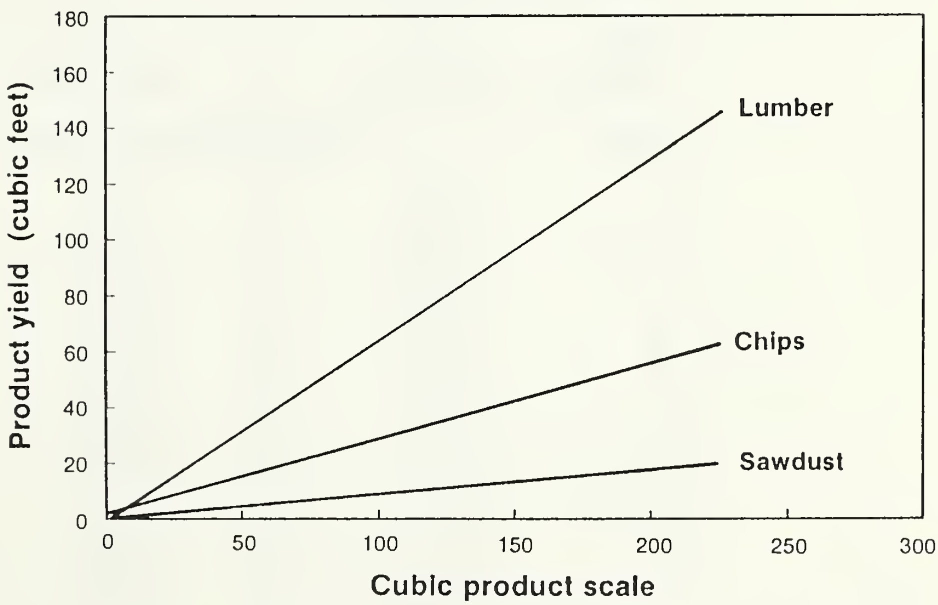

Figure 10—The relation of yield in cubic feet of rough green lumber, chips, and sawdust to cubic product scale. Regression equations are shown in appendix 3.

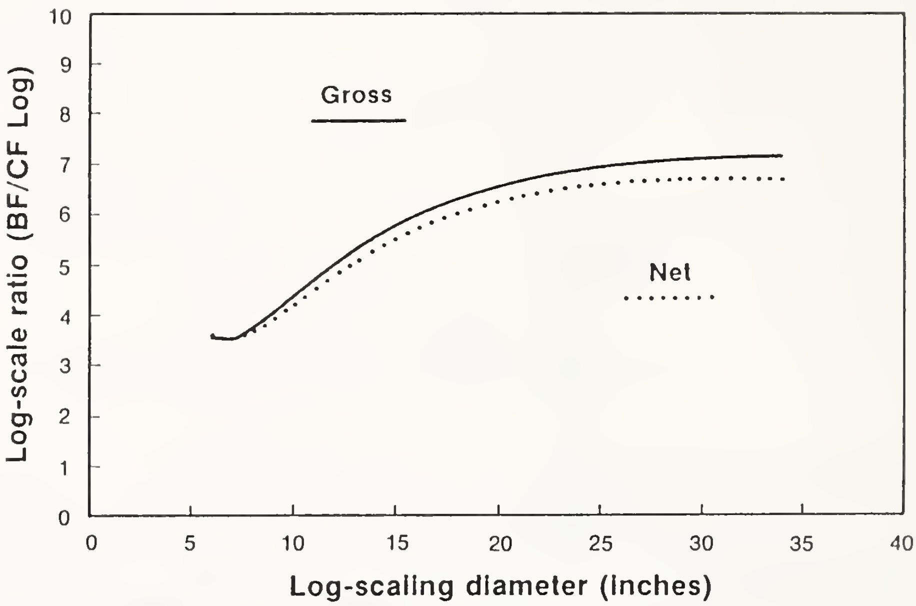

Figure 11—The relation of Scribner to cubic log-scale ratios to log diameter. Regression equations are shown in appendix 3.

Table 11—The ratio of Scribner board-foot scale to cubic-foot scale, by scaling diameter with 95-percent confidence interval (CI)

Scaling diameter	Gross BF/CF Log[a]	CI[b]	Net BF/CF Log[a]	CI[b]
Inches	----------Board feet per cubic foot---------			
6	3.55	0.25	3.59	0.38
8	3.74	.14	3.64	.22
10	4.39	.13	4.22	.20
12	5.03	.11	4.80	.17
14	5.56	.10	5.29	.15
16	5.98	.10	5.68	.16
18	6.31	.11	5.99	.17
20	6.56	.11	6.22	.17
22	6.76	.11	6.39	.17
24	6.90	.11	6.52	.17
26	7.01	.13	6.60	.20
28	7.08	.16	6.66	.25
30	7.12	.21	6.68	.32
32	7.14	.26	6.69	.40
34	7.13	.32	6.67	.49

[a]Regression equations listed in appendix 3.

[b]CI is the half-width of 95-percent confidence limit for the expected mean value of the dependent variables, BF/CF Log gross and BF/CF Log net.

Metric Equivalents

1 inch = 2.54 centimeters

1 foot = 0.3048 meter

1 cubic foot = 0.02832 cubic meter

1 pound = 453.6 grams

1 ton = 0.907185 metric ton

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Appendix 1

Incense-cedar lumber-recovery and log-scale data available from PNW. Recovery is based on the woods-length log. Two records are available for each log.

First record (card type = 1)—

Information	Columns
Card type (1)	1 - 1
Tree/log number	2 - 5
Scribner log length	9 - 10
Large-end diameter	14 - 15
Small-end scaling diameter	19 - 20
Scribner gross board-foot scale	21 - 25
Scribner net 1-3/4-board-foot scale[1]	26 - 30
Scribner net 4-1/2-board-foot scale[2]	31 - 35
Board-foot lumber tally with cull boards	36 - 40
Board-foot lumber tally without cull boards	41 - 45
Gross cubic scale[3]	46 - 51
Product cubic scale[4]	52 - 57
Surface dry cubic-foot lumber tally	58 - 64
Sawdust volume in cubic feet	65 - 71
Rough green cubic-foot lumber tally	72 - 78

Second record (card type = 2)—

Information	Columns
Card type (2)	1 - 1
Tree/log number	2 - 5
Percent recovery in:	
Moulding	6 - 10
Factory Selects	11 - 15
1 Shop	16 - 20
2 Shop	21 - 25
3 Shop	26 - 30
Shop Outs	31 - 35
1 Common	36 - 40
2 Common	41 - 45
3 Common	46 - 50
4 Common	51 - 55
5 Common	56 - 60

[1] The rules for scaling pecky rot were modified in this study. Pockets of rot were squared out and deducted only if they were less than 1-3/4 inches apart; all other pockets were ignored.

[2] The rules for scaling pecky rot were modified in this study. Pockets of rot were squared out and deducted only if they were less than 4-1/2 inches apart; all other pockets were ignored.

[3] Gross cubic log volumes were calculated using two formulas: Bruce's formula for the butt segment and Smalian's formula for all other logs.

[4] Cubic product scale is gross cubic scale reduced for all defects expected to reduce the yield of primary and secondary products.

Appendix 2

Definitions and Formulas for Measures of Product Recovery

Board-foot recovery percent—The board-foot lumber tally divided by net Scribner log scale:

$$\frac{\text{Board-foot lumber tally}}{\text{Scribner net log scale}} \times 100\ .$$

Cubic-lumber recovery percent—The cubic-foot volume of rough green lumber divided by the cubic product scale:

$$\frac{\text{Cubic-foot lumber volume}}{\text{Cubic product scale}} \times 100\ .$$

Cubic-foot lumber volume was calculated by applying measurements of rough green lumber to the shipping tally.

Cubic sawdust-recovery percent—The cubic-foot volume of sawdust divided by the cubic product scale:

$$\frac{\text{Cubic-foot volume of sawdust}}{\text{Cubic product scale}} \times 100\ .$$

Sawdust volume is estimated using the surface area of the lumber and an average saw kerf.

Cubic chip-recovery percent—The cubic volume of chippable log residue divided by the cubic product scale:

$$\frac{\text{Cubic-foot volume of chippable residue}}{\text{Cubic product scale}} \times 100\ .$$

Chippable residue is estimated by subtracting the cubic volume of rough green lumber plus the cubic volume of sawdust from the cubic product scale.

Board foot per cubic foot of lumber (BF/CF Lum)—The nominal board-foot lumber tally divided by the rough green cubic-foot volume of lumber:

$$\text{BF/CF Lum} = \frac{\text{board-foot lumber tally}}{\text{cubic-foot volume of rough green lumber}}\ .$$

Percent lumber-grade recovery—The proportion of total board-foot lumber volume in each lumber grade group:

$$\frac{\text{Board-foot lumber volume for any grade group}}{\text{Total board-foot lumber volume}} \times 100\ .$$

Dollars per thousand board-foot lumber tally—The total value of the lumber manufactured divided by the lumber tally:

$$\$/MLT = \frac{\text{lumber value}}{\text{board-foot lumber tally}} .$$

Dollars per thousand net Scribner log scale—Computed using the previously defined recovery ratios of board-foot recovery percent and $/MLT:

$$\$/MNLS = \text{board-foot recovery percent} \times \$/MLT.$$

Dollars per hundred cubic feet of cubic product scale—Computed using the previously defined recovery ratios BF/CF Lum, cubic recovery percent of rough green lumber, and $/MLT:

$$\$/CCF = \text{BF/CF Lum} \times \text{cubic recovery percent of rough green lumber} \times \text{BF/CF Lum} .$$

Board feet of log scale per cubic foot of log scale—The Scribner log-scale volume divided by the cubic log-scale volume. Two ratios are calculated—one for gross scale and one for net scale:

$$\text{BF/CF Log gross} = \frac{\text{gross Scribner scale}}{\text{gross cubic scale}} \text{; and}$$

$$\text{BF/CF Log net} = \frac{\text{net Scribner scale}}{\text{cubic product scale}} .$$

Appendix 3

List of regression equations used to generate figures and tables for incense-cedar. Formulas used to calculate dependent variables are shown in appendix 2.

Dependent variable	Regression model	R^2	SE	Table	Figure
	Lumber recovery equations				
Board-foot recovery percent	89.1+476.7(1/D)	0.18	40.26	3	2
Board-foot recovery percent	$77.0+523.7(1/D)+0.034(DEF)^2$	.38	35.53	4	
Cubic lumber recovery percent	$140.9-1.46(D)-1089(1/D)+3581(1/D)^2$	.29	10.72	5	4
Cubic lumber plus sawdust percent	$154.7-1.53(D)-1171(1/D)+3874(1/D)^2$	.28	12.03	5	4
BF/CF Lum	10.34+0.915(1/D)	.18	.08	6	
	Lumber grade recovery equations[a]				
Percent 5 Common	8.0 (no relation with diameter)			7	5
Percent 4 + 5 Common	52.9-0.8(D)-201.2(1/D)	.03	22.10	7	5
Percent all Commons (5+4+3+2+1)	$72.3+7.36(D)-0.876(D)^2+0.106(D)^{2.5}$	.74	13.19	7	5
Percent all Commons plus Shops	$96.85+0.8(D)-0.049(D)^2$	.49	7.27	7	5
Percent Moulding	100 percent – all Commons plus Shops			7	5
Percent 5 Common	4.08+0.48(DEF)	.19	13.35		6
	Lumber value equations[b]				
$/MLT	$-108.0+13.06(D)+3260.8(1/D)-9245.7(1/D)^2$	.32	56.19	9	7
$/MLT	$-100.3+13.34(D)+3247.9(1/D)-9333.2(1/D)^2-1.19(DEF)$	.38	53.78	10	
	Direct product equations				
Lumber yield in cubic feet	-0.88+0.65(cubic product scale)	.96	7.23		10
Chip yield in cubic feet	1.66+0.27(cubic product scale)	.75	8.34		10
Sawdust yield in cubic feet	-0.09+0.09(cubic product scale)	.97	.83		10
	Log-scale conversion factors				
BF/CF Log gross	$13.19-0.807(D)-116.15(1/D)+368.77(1/D)^2$	.76	.71	11	
BF/CF Log net	$12.83-0.092(D)-114.0(1/D)+371.1(1/D)^2$	.52	1.10	11	

D = scaling diameter in inches,
DEF = percent of Scribner scaling defect,
R^2 = coefficient of determination, and
SE = standard error of the regression.

[a]Grade-recovery equations are cumulative. To estimate the percent in any one grade group, the percent of the previous grade group must be subtracted. For example, to estimate the percent of 4 Common lumber, the percentage of 5 Common is subtracted from the estimate for 4 + 5 Common.
[b]$/MLT based on 1985 prices.

GPO 593-223/80100

Pong W.Y.; Cahill, James M. 1988. Lumber recovery from incense-cedar in central California. Res Pap. PNW-RP-393. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

A sample of 130 incense-cedar (*Libocedrus decurrens* Torr.) trees was selected from the Eldorado National Forest in California. The trees were felled and bucked into 403 woods-length logs and processed through a sawmill cutting Shop and Common grades of lumber. Recovery estimates are shown for woods-length logs based on Scribner board-foot scale and cubic-foot scale. Analysis showed that board-foot recovery ranged from 169 percent for 6-inch logs to 103 percent for 34-inch logs. Cubic-volume recovery of rough green lumber increased from 50 percent to 62 percent for the same range of diameters. Yields of higher quality lumber (Shops and Moulding) increased as log diameter increased. Percentage of Scribner scaled defect was found to be correlated with several measures of product recovery.

Keywords: Lumber recovery, lumber value, incense-cedar, log scale, California.

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