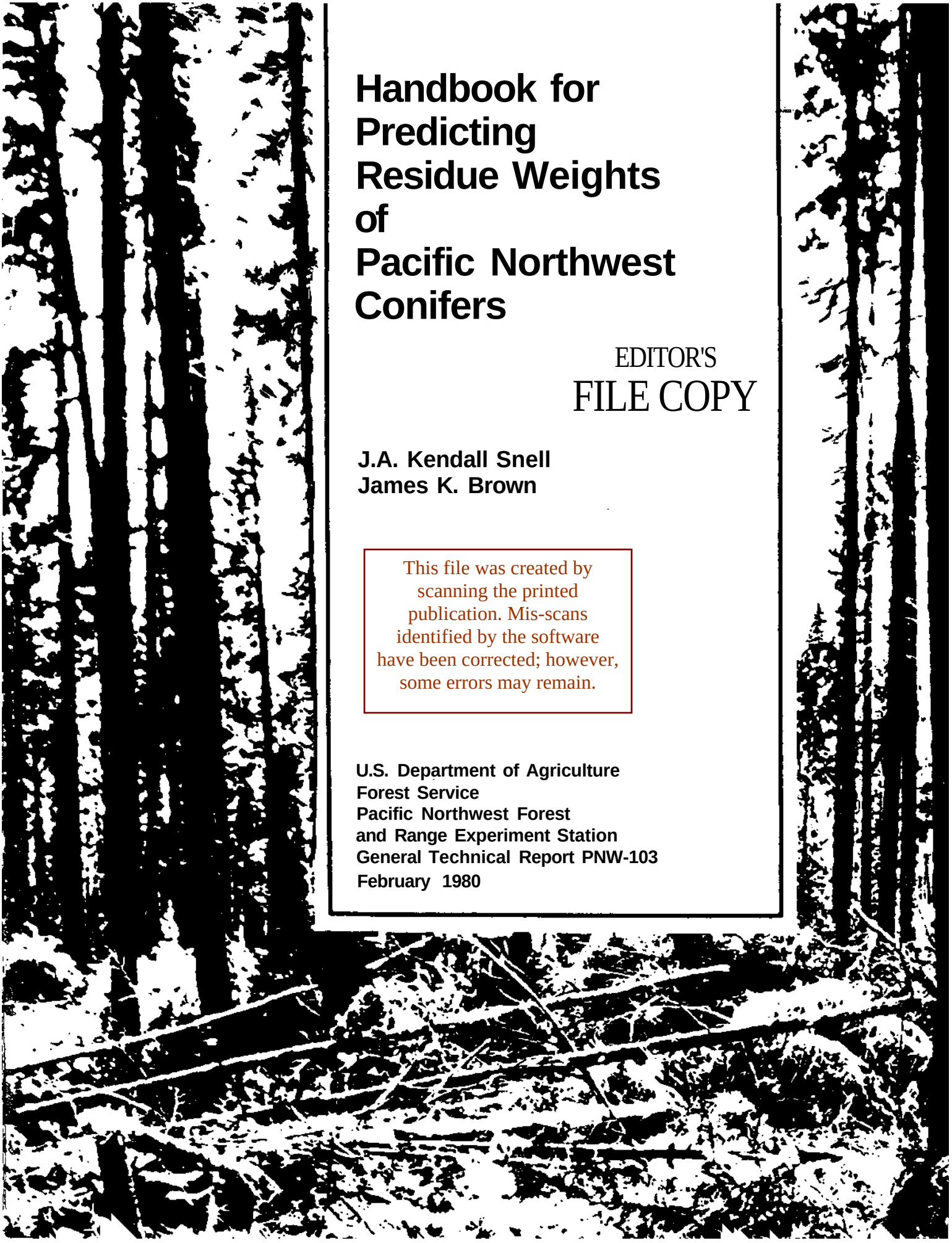

Handbook for Predicting Residue Weights of Pacific Northwest Conifers

EDITOR'S
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ABSTRACT

Procedures are given for estimating weights of potential residue from Douglas-fir and western hemlock created by forest management activities west of the summit of the Cascade Range. Preliminary estimates are given for six other species. The weight tables are in pounds per tree and pounds per square foot of basal area for a **6-** or 8-inch unmerchantable tip. The estimates are also separated into material of: <3-inch and ≥3-inch diameter and total weight. The tabular weights include foliage, live and dead branchwood, and unmerchantable tip.

KEYWORDS: Biomass, residue weights, conifers, weight tables.

PREFACE

This handbook provides instructions and information for predicting crown weights of conifers west of the summit of the Cascade Range. It is an extension of the "Handbook for Predicting Slash Weight of Western Conifers," by Brown et al. (1977). That handbook was intended for use in predicting crown weight of conifers in western Montana and northern Idaho, but its use has grown to include all the Northwest United States east of the summit of the Cascade Range. Other than geographical use of these two handbooks, the principal difference is the addition, in this handbook, of the weight table for material >3-inch diameter and the extension of diameter at breast height (d.b.h.) from 40 to 80 inches. The extension of the tables beyond 40-inch d.b.h. is based on data collected for Douglas-fir and western hemlock. The weights for other species beyond 40-inch d. b. h. were developed from weight ratios with Douglas-fir at 40-inch d.b.h. (see tables 12 and 13 in the appendix).

Special thanks are due James Atkins for expediting compilation of the tables through efficient programing.

CONTENTS

TABLES

APPROXIMATE CONVERSIONS TO METRIC UNITS

When you know	multiple by	to find
inches	2.540	centimeters
feet	0.305	meters
pounds	0.454	kilograms
pounds/square foot	4.003	kilograms/square meter
tons/acre	2.242	metric tonnes/hectare
cubic feet/acre	0.070	cubic meters/hectare

Scientific and Common Names of Tree Species

Scientific name	Common name
Abies amabilis Dougl. ex Forbes	Pacific silver fir
Abies concolor (Gord. and Glend.) Lindl. ex Hildebr.	white fir
Abies grandis (Dougl. ex D. Don) Lindl.	grand fir
Abies lasiocarpa (Hook.) Nutt.	subalpine fir
Abies maqnifica var. shastensis Lemm.	shasta red fir
Abies procera Rehd.	noble fir
Chamaecyparis nootkatensis (D. Don) Spach	Alaska-cedar
Larix occidentalis Nutt.	western larch
Libocedrus decurrens Torr.	incense-cedar
Picea engelmannii Parry ex Engelm.	Engelmann spruce
Picea glauca (Moench) **Voss**	white spruce
Picea sitchensis (Bong.) Carr.	Sitka spruce
Pinus albicaulis Engelm.	whitebark pine
Pinus attenuata Lemm.	knobcone pine
Pinus contorta Dougl. ex Loud.	lodgepole pine
Pinus jeffreyi Grev. and Balf.	Jeffrey pine
Pinus lambertiana Dougl.	sugar pine
Pinus monticola Dougl. ex D. Don	western white pine
Pinus ponderosa Dougl. ex Laws.	ponderosa pine
Populus tremuloides Michx.	quaking aspen
Populus trichocarpa Torr. and Gray	black cottonwood
Pseudotsuqa menziesii (Mirb.) Franco var menziesii	coast Douglas-fir
Sequoia sempervirens (D. Don) Endl.	redwood
Thuja plicata Donn ex D. Don	western redcedar
Tsuqa heterophylla (Raf.) Sarg.	western hemlock

INTRODUCTION

This handbook contains procedures for predicting weights of logging and thinning residue, such as needles, branches, unmerchantable tips, and broken and defective boles. In the past, this residue has been difficult to quantitatively describe before it was created, and associated problems were difficult to determine and evaluate. Prediction of such material does not guarantee easy solutions to management problems but rather provides a sound foundation for making decisions and formulating plans.

Weight estimates of residue can be useful in the following situations: (1) communicating the magnitude of residue problems, (2) writing disposal. contracts, (3) describing potential for utilization, (4) selecting among alternative treatments, and (5) appraising potential fire behavior of fuels.

Residue is produced from three parts of a tree: (1) crowns (foliage and branches), (2) unmerchantable tips, and (3) defective and broken boles (fig. 1). Tables 1–10 include the crown and unmerchantable tip weights, but they do not include the defective and broken boles; this weight must be estimated by a separate procedure (see page 4).

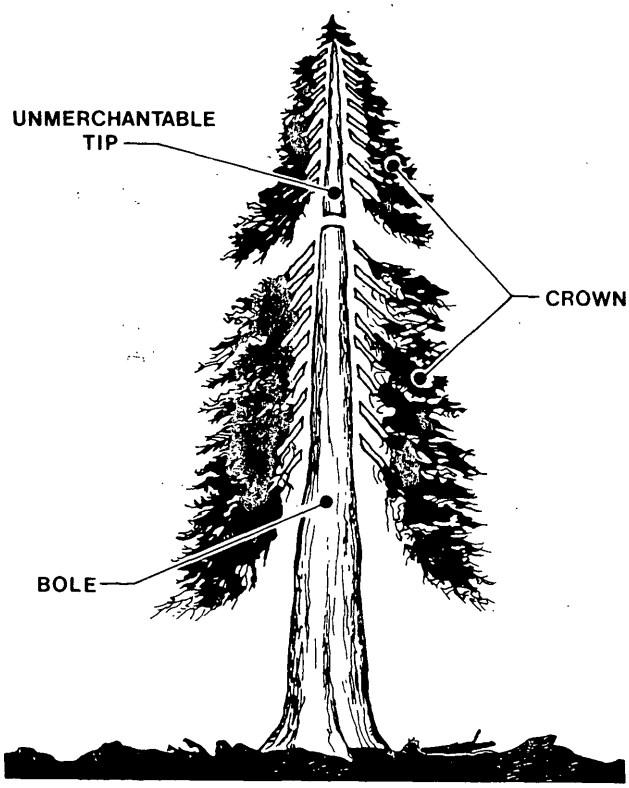

Figure 1.--Different relationships are required to predict weight of residue produced from crowns (foliage and dead and live branchwood), unmerchantable bole tips, and boles (defective and broken).

The weights in tables 1–10 were derived from studies by Brown (1978), Faurot (1977), and the Forest Residue Program, Pacific Northwest Forest and Range Experiment Station.[1] For explanations, see the appendix.

Predicting weights of created residue for many different species and tree sizes is a job for computers. Computer programs for calculating such weights have been developed for some Regions of the USDA Forest Service. Since these programs are not readily available to everyone, this handbook was assembled to be used as a substitute to calculate potential residue weights when access to computer prediction programs is not available or is inconvenient'.

The total amount of residue after logging or thinning is the sum of the residue present before and after logging or thinning. The residues present before logging or thinning can be of major importance for evaluating fire potential; sometimes this material weighs as much as or more than the created residue.

PROCEDURES USED TO MAKE RESIDUE PREDICTIONS

Residue weights can be predicted for cut or trampled trees from estimates of (1) trees per acre by species and d.b.h. or (2) basal area per acre by species and d.b.h. Tables 1–10 include weights of crowns (foliage, live and dead branchwood) and unmerchantable tips to either a 6–inch or 8–inch merchantable top diameter.

The tables are designed so the user can estimate weight of: (1) branches and unmerchantable tips that are <3 inches in diameter (includes foliage), (2) branches and unmerchantable tips that are >3 inches in diameter, and (3) total weight (sum of 1 and 2).

The separation of the material at 3 inches in diameter coincides with the required inputs for a mathematical fire appraisal program, called HAZARD.[2]

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[1] predicting crown weight of Pacific Northwest Douglas–fir and western hemlock. Unpublished data on file at Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

[2] Developed by Frank A. Albini, Northern Forest Fire Laboratory, Missoula, Montana, and maintained by the USDA Forest Service, Northern Region, Aviation and Fire Management, Missoula, Montana.

Residue weights can be predicted and summarized along with prelogging or prethinning down woody fuels in four basic steps:

1. Gather and summarize tree inventory data.
2. Calculate weight from cutting and trampling.
3. Calculate weight for tree defect and breakage.
4. Inventory down and dead woody material.

Step 1--For the area of interest, summarize inventory data of trees to be cut, by number of trees per acre by species and d.b.h., or by basal area per acre by species and d.b.h., whichever form is more convenient.

Summarize the tree inventory data by 1-inch d.b.h. classes, or by d.b.h. groups; use the average d.b.h. of each group for determining weights (for example, for 5-10 inches, use midpoint--8). Residue weight from both cutting and trampling can be estimated for the area by including in the summary only the trees that are expected to be either cut or trampled (trampling is the pushing over of small trees by logging equipment). Trampling seldom occurs in thinning operations and may be negligible in many harvesting areas. Where substantial trampling is expected, however, its contribution to residue can be estimated by procedures described later.

Step 2--Select the desired weight table and multiply either the number of trees or the basal area per acre times the appropriate table values for crown weight for each species d.b.h. group. Sum all weights to obtain the total crown weight per acre.

For harvest cutting, choose the appropriate weight table--either for material <3-inch diameter, >3-inch diameter, or total--for either a 6- or 8-inch merchantable top diameter. If the top diameter specification is other than 6 or 8 inches, use the one that most closely approximates the specified top diameter.

Since trees being thinned or trampled are generally small, their entire bole is left onsite. For these trees, the values above the dashed line in tables 2, 3, 4, 5, 7, 8, 9, and 10 should be used, since these weights include the entire bole and crown. It must be remembered, though, that some tables contain only that portion of the weight that is >3 inches in diameter. For trees below the dashed line, only the unmerchantable tip and crown weight are included: that portion of the bole below the unmerchantable tip is excluded.

Step 3--Estimate residue weight for tree defect and breakage.

Defect and breakage of trees are far more difficult to predict than weights of crowns and unmerchantable tips. Nonetheless, an estimate is possible from experience and knowledge of local harvesting operations. This estimate cannot be obtained from the enclosed tables, but a general procedure describing how to estimate these weights will be given. Residue from defect and breakage is considered larger than 3 inches in diameter and should be added only to weights obtained from the >3 inches and total weight tables.

Defect--such as rot, crook, sweep, fire scars, butt swell, etc.--varies by species and tree size. Most timber sellers have some notion of defect percentage (fraction of merchantable volume that is defective) applicable to their area. Not all defect remains on the cutting site, however; some of it is hauled to the mill. Thus, defect percentages must represent the material actually remaining onsite.

Breakage can best be estimated from local experience with past harvesting operations. In the Pacific Northwest, breakage in old-growth stands is commonly estimated at 15 percent of the cruised merchantable volume. For second-growth stands, 5 percent is not uncommon (opinions of several experienced foresters in USDA Forest Service Pacific Northwest Region).

To make weight estimates of either breakage or defect, an estimate of merchantable volume per acre is needed. This volume may be obtained from a timber cruise or formal stand examination. Wood densities (weight per unit volume) are then used to change volume to weight. Densities for common western tree species are summarized in table 11. For a mixture of species, densities can be averaged. A wood density representing a commonly encountered mixture of western conifer species is 25 pounds per cubic foot.

Step 4--Inventory the weight of dead and down woody material and add it to appropriate weight predicted from weight tables.

Refer to Brown's (1974) "Handbook for Inventory Downed Woody Material."

Sample Prediction

To illustrate the steps used to estimate weight of potential residue from the tables, consider a partial harvest of Douglas-fir and western hemlock. The specified merchantable top diameter for this example is 8 inches. The trees to be cut are summarized by species and d.b.h. on the RESIDUE WEIGHT SUMMARY form (fig. 2). The four steps are the guide for this example. As an aid to the user, a blank RESIDUE WEIGHT SUMMARY form is included at the back of this publication.

STAND 16 LOCATION DEEP CR. UNIT 1 DATE 5-15-79

<3 _____ ≥3 _____ TOTAL X TOP DIA. 8.0

Number of trees/acre from inventory by species							Crown weight/acre (pounds) by species					
DBH	DF	WH					DF	WH				
1		60						168				
2		30						369				
3		—						—				
		90						537				
10												
12		12						5208				
14		6						2736				
16												
18		4						2176				
20		5						3025				
22	2	2					1274	1352				
24	3						2133					
26	2						1692					
	—	—					—	—				
	7	29					5,099	+ 14,497	= 19,596			

SUMMARY OF RESIDUE WEIGHT

(1) CUTTING		(2) TRAMPLING		(3) DEF. & BREAKAGE	
Pounds/acre	Tons/a cre	Pounds/a cre	Tons/a cre	Pounds/acre	Tons/a cre
19596	9.8	537	.27	8527	4.26

PREDICTED WEIGHT, (1) + (2) + (3) Tons/acre = 14.33

(4) EXISTING DOWNED RESIDUE, Tons/acre = 18.00

TOTAL RESIDUE (1) + (2) + (3) + (4), Tons/acre = 32.33

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Figure 2.--A completed residue weight summary form.

(1) CUTTING:

Step 1--Estimate number of trees to be cut per acre, by species and d.b.h., and record on left side of RESIDUE WEIGHT **SUMMARY** form (fig. 2). In this example, there are 29 western hemlock (12- to 22-inch d.b.h.) and 7 Douglas-fir (22- to 26-inch d.b.h.) trees per acre to be cut. It is also estimated that 90 western hemlock trees (1- and 2-inch d.b.h.) per acre will be trampled.

Step 2--Select the appropriate weight table to be used. For this example table 5 will be used because total residue weight is needed for a merchantable top specification of 8 inches.

Example: There will be 12 western hemlock trees with a d.b.h. of 12 inches cut per acre. The residue weight estimate for a 12-inch d.b.h. western hemlock is **434** pounds (table 5); thus,

12 x **434** = 5,208 lb/acre.

The remaining trees per acre are similarly estimated; summed, the total is 9.80 tons/acre.

(2) TRAMPLING: It was estimated that sixty 1-inch d.b.h. and thirty 2-inch d.b.h. western hemlock will be trampled. Their predicted weight is:

[(60 x 2.8)+(30 x 13.3)]+2,000 =0.27 ton/acre.

(3) DEFECT AND BREAKAGE:

Step 3--A timber cruise indicated the volume to be harvested was 2,992 ft3 per acre, 80-percent western hemlock and 20-percent Douglas-fir. Of the merchantable volume per acre, about 10 percent will be left in the woods; 5 percent for defect and 5 percent for breakage. To change volume to weight, multiply by a weighted average density. See table 11 for densities of species. For this example, the weighted density would be:

[80 percent x 28.1 + 20 percent x 30.0]/100 = 28.5.

The volume left onsite is then changed to weight by the following formula:

$$W = V \times f \times s/2{,}000;$$

where:

W = weight of logging residue from defect and breakage, tons/acre;
V = merchantable volume of trees to be cut, ft3/acre;
f = fraction of merchantable volume expected to be left on the ground as defect and breakage;
s = density of wood, lb/ftg3; and
2,000 changes pounds to tonnes.

For this example:

V = 2,992 ft3;
f = 0.05 defect plus 0.05 breakage which equals 0.10;
s = 28.5 lb/ft3 (weighted average previously calculated); and
W = (2,992 x 0.10 x 28.5)+2,000 = 4.26 ton/acre.

Residue predicted from cutting, trampling, and defect and breakage is: 9.80 + 0.27 + 4.26 = 14.33 ton/acre.

(4) DEAD AND DOWN WOODY MATERIAL:

Step 4--An inventory of dead and down woody material in the area yielded 18.00 tons/acre.

Total residue predicted, then, is: 14.33 + 18.00 = 32.33 ton/acre.

Other Species and Crown Classes

Procedures outlined in the previous section can be used with unknown but probably acceptable accuracy on species that have branching habits similar to the species listed in the tables. The following combinations of species are probably similar enough to yield reasonably accurate residue predictions when considered alike:

Listed in tables	Like species not listed in tables
Lodgepole pine	Knobcone and white bark pine
Grand fir	Shasta red fir and white fir
Western redcedar	Incense–cedar
Western white pine	Sugar pine
Ponderosa pine	Jeffrey pine

The tables in this handbook were developed from data for trees having dominant and codominant crown classes.[3] Brown (1978) found that crown weight of intermediate trees of shade–tolerant species is not significantly different from that of dominant and codominant trees. For shade-intolerant species, however, crown weight of intermediate trees is significantly less than that of dominant and codominant trees. Thus, in stands of tolerant species where a large proportion of the trees have intermediate crowns, an adjustment of the crown weight based on dominant and codominant trees may be desirable.

We recommend adjusting crown weights only for ponderosa pine, lodgepole pine, and western larch. When these species dominate the composition and have a high proportion of intermediate trees, adjusted crown weights can be calculated as follows:

D.b.h.	Equation
Less than 7.5 inches	$D' = D(1 - 0.5fI)$
7.5 inches and greater	$D' = D(1 - 0.4fI)$

where:

D' = crown weight per acre adjusted for intermediate trees,
D = crown weight per acre based on dominant and codominant trees, and
fI = fraction of trees per acre having intermediate and suppressed crowns.

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heights for Douglas–fir were developed from trees of all crown classes.

Residue Weight (lb) per TREE

TABLE 1--WEIGHT OF RESIDUE PER TREE BY D.B.H., OF FOLIAGE AND THAT PORTION OF THE BRANCHWOOD (LIVE AND DEAD), AND UNMERCHANTABLE TIP THAT IS ≤3 INCHES IN DIAMETER

	≤3 INCHES							
	SPECIES[1]							
D.B.H.	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[2]							
1	2.9	3.1	2.4	2.1	3.7	3.8	2.8	5.0
2	11.6	11.9	9.8	11.2	12.1	12.7	11.3	17.2
3	18.1	21.6	16.7	20.3	19.0	21.2	18.3	29.5
4	29	37	26	33	29	33	29	47
5	40	54	35	46	38	46	41	66
6	57	78	47	64	51	62	58	90
7	74	104	58	77	60	79	71	113
8	90	131	65	95	70	96	87	139
9	109	161	75	116	82	115	107	168
10	129	193	86	137	94	135	12a	198
11	148	222	97	154	105	152	150	224
12	169	254	108	173	116	171	173	252
13	191	288	121	193	128	191	199	281
14	216	324	135	215	141	212	227	312
15	240	362	150	238	155	235	256	345
16	268	403	165	263	169	258	288	378
17	296	445	181	290	183	282	321	413
18	327	489	198	318	199	308	356	450
19	359	535	215	348	215	334	394	488
20	393	583	233	379	231	361	433	527
21	428	631	252	412	248	390	473	568
22	465	681	271	446	265	419	516	611
23	503	732	291	482	283	449	561	654
24	542	784	311	520	301	481	607	699
25	586	839	336		342	536	659	767
26	628	892	358		360	568	709	814
27	672	947	380		378	601	760	863
28	716	1000	403		398	634	814	913
29	763	1060	426		417	669	870	965
30	810	1110	450		437	705	927	1020
31	859	1170	475		458	741	986	1070
32	908	1220	500		479	779	1040	1130
33	959	1280	525		500	818	1090	1190
34	1010	1330	552		522	857	1140	1250
35	1060	1410	578		545	898	1190	1310
36	1120	1500	606		567	939	1240	1370
37	1170	1580	634		591	982	1290	1430
38	1230	1670	663		614	1030	1340	1500
39	1290	1760	692		638	1070	1390	1570
40	1350	1860	721		662	1110	1450	1630

TABLE 1--CONTINUED

D.B.H.	SPECIES[1]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[2]							
41	1400	1950	761		700	1160	1500	1720
42	1460	2050	797		732	1220	1550	1810
43	1520	2140	834		765	1280	1600	1890
44	1590	2240	872		799	1340	1650	1980
45	1650	2340	911		833	1400	1730	2080
46	1710	2440	950		868	1460	1800	2170
47	1770	2550	990		904	1520	1880	2270
48	1840	2660	1030		941	1580	1950	2370
49	1900	2770	1070		978	1650	2030	2470
50	1970	2880	1120		1020	1720	2110	2570
51	2040	2990	1160		1060	1790	2190	2680
52	2100	3110	1200		1100	1860	2280	2790
53	2170	3230	1250		1140	1930	2360	2900
54	2240	3350	1300		1180	2000	2450	3020
55	2300	3470	1340		1220	2080	2540	3140
56	2370	3600	1390		1260	2150	2630	3260
57	2440	3730	1440		1300	2230	2720	3380
58	2510	3860	1490		1350	2310	2810	3510
59	2580	3990	1540		1390	2390	2910	3640
60	2650	4130	1590		1440	2470	3010	3770
61	2720					2550	3100	3900
62	2790					2640	3200	4040
63	2860					2730	3300	4180
64	2930					2810	3410	4320
65	3000					2900	3510	4470
66	3070					2990	3620	4620
67	3150					3090	3720	4770
68	3220					3180	3830	4930
69	3290					3280	3940	5080
70	3360					3370	4060	5240
71	3430					3470		
72	3500					3570		
73	3570					3680		
74	3650					3780		
75	3720					3880		
76	3790					3990		
77	3860					4100		
78	3930					4210		
79	4000					4320		
80	4070					4430		

1DF = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

2OVENDRY WEIGHT.

TABLE 2--WEIGHT OF RESIDUE PER TREE BY D.B.H., OF THAT PORTION OF THE BRANCHWOOD AND UNMERCHANTABLE TIP THAT IS >3 INCHES IN DIAMETER FOR A 6-INCH UNMERCHANTABLE TIP

6-INCH TIP, >3-INCHES

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	.0	.0	.0	.0	.0	.0	.0	.0
2	1.1	.7	.8	.9	.9	.7	1.0	.9
3	14.4	9.9	14.7	16.3	12.5	9.2	14.3	12.1
4	35	25	40	42	32	23	37	31
5	69	50	82	83	66	45	74	62
6	113	82	138	134	112	73	123	106
7	128	102	149	96	94	77	105	93
8	114	97	129	82	84	70	94	83
9	104	93	114	71	83	65	98	79
10	95	90	102	63	76	60	91	71
11	89	89	93	57	70	56	86	66
12	83	90	88	52	65	53	81	61
13	78	93	83	47	61	50	77	58
14	74	97	79	43	57	48	74	54
15	73	103	75	40	55	46	70	52
16	71	112	73	37	52	44	68	50
17	69	122	71	35	50	42	65	48
18	68	135	69	33	48	41	63	46
19	68	150	68	31	46	39	61	45
20	68	167	67	29	45	38	59	43
21	69	187	66	28	43	37	57	42
22	70	210	66	27	42	36	55	41
23	71	236	65	25	41	35	54	40
24	73	264	65	24	40	34	52	39
25	96	310	99		40	34	79	39
26	99	345	99		40	34	77	39
27	102	383	99		40	34	75	39
28	106	425	99		40	34	74	39
29	111	470	100		40	34	72	39
30	116	519	100		40	34	71	39
31	122	572	101		40	34	69	39
32	129	630	101		40	34	79	39
33	137	691	102		40	34	91	39
34	145	757	103		40	34	103	39
35	155	799	104		40	34	118	39
36	165	844	104		40	34	134	39
37	176	890	105		40	34	151	39
38	188	937	106		40	34	170	39
39	200	986	107		40	34	191	39
40	214	1040	108		40	34	214	39

TABLE 2--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	229	1090	109		40	34	238	39
42	245	1140	111		40	34	265	39
43	262	1190	112		40	34	293	39
44	280	1240	114		40	34	324	39
45	299	1290	115		40	34	335	39
46	320	1350	117		40	34	346	39
47	341	1400	119		40	34	357	39
48	364	1460	121		40	34	369	39
49	389	1520	123		40	34	381	39
50	414	1570	125		40	34	394	39
51	441	1630	127		40	34	406	39
52	469	1700	129		40	34	419	39
53	499	1760	131		40	34	432	39
54	530	1820	133		40	34	445	39
55	563	1890	136		40	34	459	39
56	597	1950	138		40	34	473	39
57	633	2020	140		40	34	487	39
58	670	2090	143		40	34	501	39
59	709	2160	145		40	34	516	39
60	750	2230	148		40	34	530	39
61	792					34	545	39
62	836					34	561	39
63	882					34	576	39
64	930					34	592	39
65	979					34	608	39
66	1030					34	624	39
67	1080					34	641	39
68	1140					34	657	39
69	1200					34	674	39
70	1250					34	692	39
71	1320					34		
72	1380					34		
73	1440					34		
74	1510					34		
75	1580					34		
76	1650					34		
77	1730					34		
78	1800					34		
79	1880					34		
80	1960					34		

[1]ABOVE THE DASHED LINE, THE ENTIRE BOLE THAT IS >3 INCHES IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UUMERCHANTABLE TIP WEIGHT THAT IS >3 INCHES IS INCLUDED.

[2] D F = DOUGLAS–FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

[3]OVENDRY WEIGHT.

TABLE 3--TOTAL WEIGHT OF RESIDUE PER **TREE** BY D.B.H., OF FOLIAGE, BRANCHWOOD (LIVE AND **DEAD)**, AND UNMERCHANTABLE TIP **FOR** A 6-INCH UNMERCHANTABLE TIP

6-INCH TIP, TOTAL

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	2.9	3.2	2.4	2.1	3.7	3.8	2.8	5.0
2	12.6	12.6	10.6	12.1	13.0	13.4	12.3	18.1
3	32.5	31.6	31.4	36.6	31.4	30.4	32.5	41.6
4	64	62	66	75	61	56	66	78
5	110	104	117	129	104	90	115	128
6	170	160	185	198	164	136	181	196
7	202	207	207	173	154	156	176	206
8	204	228	194	177	154	166	181	222
9	212	254	189	187	165	180	205	247
10	224	283	188	201	170	195	219	270
11	236	311	191	211	174	209	236	290
12	252	344	196	224	181	224	255	313
13	270	380	204	240	189	242	276	339
14	290	421	214	258	199	260	300	367
15	313	466	225	279	209	280	327	396
16	338	514	238	301	221	302	355	428
17	366	567	251	325	233	325	386	461
18	395	624	267	351	247	348	419	496
19	427	685	203	379	261	373	454	533
20	461	750	300	408	276	400	491	571
21	497	819	318	440	291	427	530	610
22	534	891	337	473	307	455	571	652
23	574	968	356	507	324	484	614	694
24	616	1050	377	544	341	515	660	739
25	682	1150	436		382	,570	737	806
26	727	1240	457		400	602	786	853
27	774	1330	479		419	635	836	902
28	823	1430	502		438	668	888	952
29	874	1530	526		457	703	942	1000
30	926	1630	550		478	739	998	1060
31	981	1740	575		498	776	1060	1110
32	1040	1850	601		519	813	1110	1170
33	1100	1970	627		541	852	1180	1230
34	1160	2090	654		563	891	1240	1290
35	1220	2210	682		585	932	1310	1350
36	1280	2340	710		608	973	1370	1410
37	1350	2470	739		631	1020	1440	1470
38	1420	2610	768		654	1060	1510	1540
39	1490	2750	798		678	1100	1590	1600
40	1560	2900	829		703	1150	1660	1670

TABLE 3--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	1630	3040	870		740	1200,	1740	1760
42	1710	3180	908		772	1250	1810	1840
43	1790	3330	946		805	1310	1890	1930
44	1870	3480	986		839	1370	1980	2020
45	1950	3630	1030		873	1430	2060	2110
46	2030	3790	1070		908	1490	2150	2210
47	2120	3950	1110		944	1550	2230	2310
48	2200	4120	1150		981	1620	2320	2410
49	2290	4280	1200		1020	1680	2410	2510
50	2380	4450	1240		1060	1750	2510	2610
51	2480	4630	1290		1100	1820	2600	2720
52	2570	4810	1330		1140	1890	2700	2830
53	2670	4990	1380		1180	1960	2800	2940
54	2770	5170	1430		1220	2030	2900	3060
55	2870	5360	1480		1260	2110	3000	3180
56	2970	5550	1530		1300	2190	3100	3300
57	3070	5750	1580		1340	2260	3210	3420
58	3180	5950	1630		1390	2340	3320	3550
59	3290	6150	1680		1430	2420	3420	3680
60	3400	6350	1740		1480	2500	3540	3810
61	3510					2590	3650	3940
62	3630					2670	3760	4080
63	3740					2760	3880	4220
64	3860					2850	4000	4360
65	3980					2940	4120	4510
66	4100					3030	4240	4660
67	4230					3120	4360	4810
68	4360					3220	4490	4960
69	4480					3310	4620	5120
70	4610					3410	4750	5280
71	4750					3510		
72	4880					3610		
73	5020					3710		
74	5160					3810		
75	5300					3920		
76	5440					4030		
77	5580					4130		
78	5730					4240		
79	5880					4360		
80	6030					4470		

ABOVE THE DASHED LINE, THE ENTIRE BOLE IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT IS INCLUDED. THE SOLID LINE CIRCUMSCRIBES THE FIELD DATA LIMITS, EXCLUDING THE UNMERCHANTABLE TIP.

2 DF = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

3OVENDRY WEIGHT.

TABLE 4–WEIGHT OF RESIDUE PER TREE BY D.B.H., OF THAT PORTION OF THE BRANCHWOOD AND UNMERCHANTABLE TIP THAT IS >3 INCHES IN DIAMETER FOR AN 8–INCH UNMERCHANTABLE TIP

8–INCH TIP, >3 INCHES

D.B.H.[1]	SPECIES[2] DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	.0	.0	.0	.0	.0	.0	.0	.0
2	1.1	.7	.8	.9	.9	.7	1.0	.9
3	14.4	9.9	14.7	16.3	12.5	9.2	14.3	12.1
4	35	25	40	42	32	23	37	31
5	69	50	82	83	66	45	74	62
6	113	82	138	134	112	73	123	106
7	290	157	220	207	182	153	199	172
8	415	251	312	286	264	229	284	249
9	350	298	382	241	279	216	330	259
10	316	278	337	206	248	197	302	230
11	288	261	302	180	224	181	280	208
12	265	248	276	158	205	168	26G	190
13	246	239	255	141	189	157	244	176
14	230	233	237	127	176	148	229	164
15	219	230	222	115	165	140	217	154
16	208	231	210	105	155	133	206	146
17	199	234	200	97	147	126	196	139
18	191	240	191	89	140	121	187	133
19	185	249	183	83	134	116	179	127
20	180	262	177	77	129	111	172	122
21	176	277	171	72	124	107	166	118
22	172	296	167	68	119	103	160	115
23	170	317	163	64	116	99	154	111
24	169	342	159	60	112	96	149	108
25	218	408	237		112	96	213	108
26	218	440	234		112	96	207	108
27	218	475	230		112	96	202	108
28	219	514	228		112	96	197	108
29	221	556	225		112	96	192	108
30	224	603	223		112	96	188	108
31	228	654	221		112	96	184	108
32	233	709	219		112	96	191	108
33	238	769	218		112	96	200	108
34	245	833	217		112	96	211	108
35	253	874	216		112	96	223	108
36	261	917	214		112	96	237	108
37	270	961	213		112	96	252	108
38	281	1010	213		112	96	270	108
39	292	1050	212		112	96	289	108
40	305	1100	211		112	96	310	108

TABLE 4--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	319	1150	211		112	96	333	108
42	333	1200	211		112	96	358	108
43	349	1250	212		112	96	385	108
44	366	1300	212		112	96	414	108
45	385	1350	212		112	96	424	108
46	404	1410	213		112	96	434	108
47	425	1460	213		112	96	444	108
48	447	1520	214		112	96	455	108
49	470	1570	215		112	96	466	108
50	495	1630	216		112	96	477	108
51	521	1690	217		112	96	489	108
52	549	1750	218		112	96	501	108
53	578	1810	219		112	96	513	108
54	608	1880	221		112	96	525	108
55	640	1940	222		112	96	538	108
56	674	2010	224		112	96	551	108
57	709	2070	225		112	96	564	108
58	746	2140	227		112	96	578	108
59	784	2210	229		112	96	592	108
60	825	2280	231		112	96	606	108
61	866				112	96	620	108
62	910				112	96	635	108
63	955				112	96	650	108
64	1000				112	96	665	108
65	1050				112	96	680	108
66	1100				112	96	696	108
67	1160				112	95	712	108
68	1210				112	96	728	108
69	1270				112	96	744	108
70	1330				112	96	761	108
71	1390				112	96		
72	1450				112	96		
73	1510				112	96		
74	1580				112	96		
75	1650				112	96		
76	1720				112	96		
77	1790				112	96		
78	1870				112	96		
79	1950				112	96		
80	2030				112	96		

[1] ABOVE THE DASHED LINE, THE ENTIRE BOLE THAT IS > 3 INCHES IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT THAT IS >3 INCHES IS INCLUDED.

[2] DF = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

[3] OVENDRY WEIGHT.

TABLE 5--TOTAL WEIGHT PER TREE BY D.B.H., OF FOLIAGE, BRANCHWOOD (LIVE AND DEAD), AND UNMERCHANTABLE TIP FOR AN 8-INCH UNMERCHANTABLE TIP

8-INCH TIP, TOTAL

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	2.9	3.2	2.4	2.1	3.7	3.8	2.8	5.0
2	12.6	12.6	10.6	12.1	13.0	13.4	12.3	18.1
3	32.5	31.6	31.4	36.6	31.4	30.4	32.5	41.6
4	64	62	66	75	61	56	66	78
5	110	104	117	129	104	90	115	128
6	170	160	185	198	164	136	181	196
7	364	261	278	284	242	232	270	285
8	505	382	377	380	334	325	372	388
9	459	459	456	356	362	331	437	427
10	444	470	422	344	342	332	430	428
11	435	483	399	334	329	334	429	432
12	434	502	385	331	321	340	434	442
13	437	527	376	334	317	349	443	457
14	446	557	372	342	317	360	456	476
15	459	593	372	354	320	374	473	499
16	476	634	375	369	324	391	494	524
17	495	679	381	387	331	408	517	552
18	518	730	389	407	339	428	544	583
19	544	785	398	431	349	449	573	615
20	573	844	410	456	360	472	605	650
21	604	908	423	484	372	496	639	687
22	637	977	430	514	385	522	676	725
23	673	1050	454	546	398	549	715	766
24	711	1130	471	580	413	577	756	808
25	804	1250	573		454	632	871	875
26	846	1330	592		472	664	916	922
27	890	1420	611		490	697	962	971
28	936	1510	631		510	730	1010	1020
29	984	1610	652		529	765	1060	1070
30	1030	1710	673		549	801	1110	1130
31	1090	1820	696		570	838	1170	1180
32	1140	1930	719		591	875	1230	1240
33	1200	2050	744		612	914	1290	1290
34	1260	2160	768		634	953	1350	1350
35	1320	2290	794		657	994	1410	1410
36	1380	2410	820		679	1040	1480	1480
37	1440	2540	847		703	1080	1540	1540
38	1510	2680	875		726	1120	1610	1610
39	1580	2820	904		750	1170	1680	1670
40	1650	2960	933		774	1210	1760	1740

TABLE 5--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	1720	3100	973		812	1260	1830	1830
42	1800	3250	1010		844	1320	1910	1910
43	1870	3390	1050		877	1370	1990	2000
44	1950	3540	1080		911	1430	2070	2090
45	2030	3690	1120		945	1490	2150	2180,
46	2120	3850	1160		980	1550	2230	2280
47	2200	4010	1200		1020	1620	2320	2380
48	2290	4170	1250		1050	1680	2410	2480
49	2370	4340	1290		1090	1750	2500	,2580
50	2460	4510	1330		1130	1810	2590	2680
51	2560	4680	1380		1170	1880	2680	2790
52	2650	4860	1420		1210	1950	2780	2900
53	2750	5040	1470		1250	2020	2880	3010
54	2850	5230	1520		1290	2100	2980	3130
55	2950	5410	1560		1330	2170	3080	3250
56	3050	5610	1610		1370	2250	3180	3370
57	3150	5800	1660		1420	2320	3290	3490
58	3260	6000	1720		1460	2400	3390	3620
59	3370	6200	1770		1510	2480	3500	3750
60	3480	6400	1820		1550	2570	3610	3880
61	3590					2650	3720	4010
62	3700					2740	3840	4150
63	3820					2820	3950	4290
64	3930					2910	4070	4430
65	4050					3000	4190	4580
66	4180					3090	4310	4730
67	4300					3180	4440	4880
68	4430					3280	4560	5030
69	4550					3370	4690	5190
70	4680					3470	4820	5350
71	4820					3570		
72	4950					3670		
73	5090					3770		
74	5220					3880		
75	5370					3980		
76	5510					4090		
77	5650					4200		
78	5800					4310		
79	5950					4420		
80	6100					4530		

[1]ABOVE THE DASHED LINE, THE ENTIRE BOLE IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT IS INCLUDED. THE SOLID LINE CIRCUMSCRIBES THE FIELD DATA LIMITS, EXCLUDING THE UNMERCHANTABLE TIP.

2 D F = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = UIDGEPOLE PINE; **WP** = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; **WH** = WESTERN HEMLOCK; GF = GRAND FIR.

3OVENDRY WEIGHT.

Residue Weight (lb) by

BASAL AREA

TABLE 6--WEIGHT OF RESIDUE PER SQUARE FOOT OF BASAL AREA BY D.B.H., OF FOLIAGE AND THAT PORTION OF THE BRANCHWOOD (LIVE AND DEAD), AND UNMERCHANTABLE TIP THAT IS ≤3 INCHES IN DIAMETER

≤3 INCHES, BASAL AREA

	SPECIES[1]							
D.B.H.	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[2]							
1	532.8	576.6	445.8	379.2	670.2	687.7	517.1	918.1
2	531.0	543.6	449.9	512.3	555.8	583.7	518.7	788.2
3	369.1	440.9	340.6	412.8	386.4	431.6	372.0	601
4	330	419	298	377	329	379	336	535
5	296	398	253	337	281	337	302	482
6	289	396	239	327	262	318	295	460
7	276	390	215	288	224	296	266	422
8	258	375	187	272	201	275	250	397
9	246	364	169	262	186	260	243	380
10	236	353	157	252	172	247	234	363
11	224	336	147	234	158	231	227	340
12	215	323	138	220	148	218	221	321
13	208	312	132	210	139	207	216	305
14	202	303	126	201	132	199	212	292
15	196	295	122	194	126	191	209	281
16	192	289	118	189	121	185	206	271
17	188	283	115	184	116	179	204	262
18	185	277	112	180	112	174	202	255
19	182	272	109	177	109	170	200	248
20	180	267	107	174	106	166	198	242
21	178	262	105	171	103	162	197	236
22	176	258	103	169	100	159	196	231
23	174	254	101	167	98	156	194	227
24	173	250	99	165	96	153	193	223
25	172	246	99		100	157	193	225
26	170	242	97		98	154	192	221
27	169	238	96		95	151	191	217
28	168	234	94		93	148	190	213
29	166	230	93		91	146	190	210
30	165	226	92		89	144	189	207
31	164	223	91		87	141	188	205
32	163	219	90		86	139	185	202
33	162	215	88		84	138	183	200
34	160	211	87		83	136	180	198
35	159	211	87		82	134	178	196
36	158	212	86		80	133	175	194
37	157	212	85		79	131	173	192
38	156	212	84		78	130	170	190
39	155	213	83		77	129	168	189
40	154	213	83		76	128	166	187

TABLE 6--CONTINUED

D.B.H.	SPECIES[1]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[2]							
41	153	213	83		76	127	163	188
42	152	213	83		76	127	161	188
43	151	212	83		76	127	159	188
44	150	212	83		76	127	157	188
45	149	212	82		75	126	156	188
46	148	212	82		75	126	156	188
47	147	212	82		75	126	156	188
48	146	211	82		75	126	155	188
49	145	211	82		75	126	155	189
50	144	211	82		75	126	155	189
51	143	211	82		74	126	155	189
52	143	211	82		74	126	155	189
53	142	211	82		74	126	154	190
54	141	211	81		74	126	154	190
55	140	211	81		74	126	154	190
56	139	210	81		74	126	154	191
57	138	210	81		74	126	154	191
58	137	210	81		74	126	153	191
59	136	210	81		73	126	153	192
60	135	210	81		73	126	153	192
61	134					126	153	192
62	133					126	153	193
63	132					126	153	193
64	131					126	152	194
65	130					126	152	194
66	129					126	152	194
67	128					126	152	195
68	128					126	152	195
69	127					126	152	196
70	126					126	152	196
71	125					126		
72	124					126		
73	123					126		
74	122					127		
75	121					127		
76	120					127		
77	119					127		
78	118					127		
79	118					127		
80	117					127		

1 DF = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

2 OVENDRY WEIGHT.

TABLE 7--WEIGHT OF RESIDUE PER SQUARE FOOT OF BASAL AREA BY D.B.H., OF THAT PORTION OF THE BRANCHWOOD (LIVE AND DEAD) AND UNMERCHANTABLE TIP THAT IS >3 INCHES IN DIAMETER FOR A 6-INCH UNMERCHANTABLE TIP

6-INCH TIP, >3 INCHES, BASAL AREA

	SPECIES[2]							
D.B.H.[1]	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	2.2	1.6	1.3	1.3	1.8	1.5	2.1	1.8
2	48.5	32.4	36.9	42.5	39.1	31.6	45.7	39.2
3	293.0	202.7	299.9	332.0	253.8	188.2	290.8	245.7
4	406	287	460	486	371	260	419	353
5	508	365	603	610	485	327	540	458
6	577	419	701	683	571	373	628	538
7	480	383	558	359	351	288	393	347
8	328	279	369	235	240	201	268	239
9	235	211	258	162	188	146	222	178
10	175	166	188	116	139	110	168	131
11	134	135	142	86	106	85	130	100
12	106	115	112	66	83	68	103	78
13	85	100	90	51	66	55	84	62
14	69	91	74	41	54	45	69	51
15	59	84	61	33	44	37	57	42
16	51	80	52	27	37	32	48	36
17	44	77	45	22	32	27	41	30
18	39	76	39	19	27	23	35	26
19	35	76	34	16	24	20	31	23
20	31	77	31	13	21	18	27	20
21	29	78	27	12	18	15	24	18
22	26	80	25	10	16	14	21	16
23	25	82	23	9	14	12	19	14
24	23	84	21	8	13	11	17	13
25	28	91	29		12	10	23	12
26	27	94	27		11	9	21	11
27	26	96	25		10	9	19	10
28	25	99	23		9	8	17	9
29	24	102	22		9	7	16	9
30	24	106	20		8	7	14	8
31	23	109	19		8	7	13	8
32	23	113	18		7	6	14	7
33	23	116	17		7	6	15	7
34	23	120	16		6	5	16	6
35	23	120	16		6	5	18	6
36	23	119	15		6	5	19	6
37	24	119	14		5	5	20	5
38	24	119	13		5	4	22	5
39	24	119	13		5	4	23	5
40	25	119	12		5	4	25	5

TABLE 7--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	25	118	12		4	4	26	4
42	25	118	11		4	4	28	4
43	26	118	11		4	3	29	4
44	27	117	11		4	3	31	4
45	27	117	10		4	3	30	4
46	28	117	10		3	3	30'	3
47	28	116	10		3	3	30	3
48	29	116	10		3	3	29	3
49	30	116	9		3	3	29	3
50	30	115	9		3	3	29	3
51	31	115	9		3	2	29	3
52	32	115	9		3	2	28	3
53	33	115	9		3	2	28	3
54	33	115	8		3	2	28	2
55	34	114	8		2	2	28	2
56	35	114	8		2	2	28	2
57	36	114	8		2	2	27	2
58	37	114	8		2	2	27	2
59	37	114	8		2	2	27	2
60	38	113	8		2	2	27	2
61	39	113	7			2	27	2
62	40	113	7			2	27	2
63	41	113	7			2	27	2
64	42	113	7			2	26	2
65	42	113	7			1	26	2
66	43	113	7			1	26	2
67	44	112	7			1	26	2
68	45	112	7			1	26	2
69	46	112	7			1	26	2
70	47	112	7			1	26	1
71	48	112	7			1		
72	49	112	7			1		
73	50	112	6			1		
74	51	112	6			1		
75	52	111	6			1		
76	52	111	6			1		
77	53	111	6			1		
78	54	111	6			1		
79	55	111	6			1		
80	56	111	6			1		

lABOVE THE DASHED LINE, THE ENTIRE BOLE THAT IS >3 INCHES IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT THAT IS >3 INCHES IS INCLUDED.

2 DF = DOUGLAS–FIR; PP = PONDEROSA PINE; WL= WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

3OVENDRY WEIGHT.

TABLE 8--TOTAL WEIGHT OF RESIDUE PER SQUARE FOOT OF BASAL AREA BY D.B.H., OF FOLIAGE, BRANCHWOOD (LIVE AND DEAD), AND UNMERCHANTABLE TIP FOR A 6-INCH UNMERCHANTABLE TIP

6-INCH TIP, TOTAL, BASAL AREA

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	535.0	578.3	447.1	380.6	672.0	689.2	519.2	919.9
2	579.5	576.0	486.7	554.8	594.9	615.3	564.4	827.4
3	662.0	643.5	640.5	744.8	640.1	619.9	662.8	846.8
4	736	706	759	863	700	639	755	889
5	804	763	857	946	766	664	841	940
6	866	814	941	1010	833	691	923	997
7	756	773	774	647	575	584	659	770
8	585	654	557	507	441	476	517	636
9	481	575	427	424	374	407	464	558
10	411	519	345	368	311	357	402	494
11	358	472	289	320	264	316	357	440
12	320	437	250	286	230	286	324	399
13	293	412	221	261	205	262	300	368
14	271	394	200	242	186	244	281	343
15	255	379	183	227	170	229	266	323
16	242	368	170	215	158	216	254	306
17	232	360	160	206	148	206	245	293
18	224	353	151	199	140	197	237	281
19	217	348	144	192	132	190	231	270
20	211	344	137	187	126	183	225	262
21	207	340	132	183	121	177	220	254
22	202	338	128	179	116	172	216	247
23	199	335	124	176	112	168	213	241
24	196	334	120	173	109	164	210	235
25	200	337	128		112	167	216	236
26	197	336	124		108	163	213	231
27	195	334	121		105	160	210	227
28	192	333	117		102	156	208	223
29	190	333	115		100	153	205	219
30	189	332	112		97	151	203	215
31	187	332	110		95	148	201	212
32	186	331	108		93	146	200	209
33	185	331	106		91	143	198	206
34	183	331	104		89	141	197	204
35	182	331	102		88	139	195	201
36	182	331	100		86	138	194	199
37	181	331	99		84	136	193	197
38	180	331	98		83	134	192	195
39	179	332	96		82	133	191	193
40	179	332	95		81	132	190	192

TABLE 8--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	178	331	95		81	131	189	192
42	178	331	94		80	130	189	192
43	177	330	94		80	130	188	192
44	177	329	93		79	130	187	191
45	176	329	93		79	129.	187	191
46	176	328	92		79	129	186	191
47	176	328	92		78	129	185	191
48	175	327	92		78	129	185	192
49	175	327	91		78	129	184	192
50	175	327	91		78	128	184	192
51	175	326	91		77	128	183	192
52	174	326	90		77	128	183	192
53	174	326	90		77	128	182	192
54	174	325	90		77	128	182	192
55	174	325	90		76	128	182	193
56	174	325	89		76	128	181	193
57	174	324	89		76	128	181	193
58	173	324	89		76	128	181	193
59	173	324	89		76	128	180	194
60	173	324	88		75	128	180	194
61	173					128	180	194
62	173					127	180	195
63	173					127	179	195
64	173					127	179	195
65	173					127	179	196
66	173					127	179	196
67	173					127	178	196
68	173					128	178	197
69	173					128	178	197
70	173					128	178	198
71	173					128		
72	173					128		
73	173					128		
74	173					128		
75	173					128		
76	173					128		
77	173					128		
78	173					128		
79	173					128		
80	173					128		

[1]ABOVE THE DASHED LINE, THE ENTIRE BOLE IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT IS INCLUDED.' THE SOLID LINE CIRCUMSCRIBES THE FIELD DATA LIMITS, EXCLUDING THE UNMERCHANTABLE TIP.

[2] D F = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE: WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

[3]OVENDRY WEIGHT.

TABLE 9--WEIGHT OF RESIDUE PER SQUARE FOOT OF BASAL AREA BY D.B.H., OF THAT PORTION OF THE BRANCHWOOD (LIVE AND DEAD) AND UNMERCHANTABLE TIP THAT IS >3 INCHES IN DIAMETER FOR AN 8-INCH UNMERCHANTABLE TIP

8-INCH TIP, >3 INCHES, BASAL AREA

	SPECIES[2]							
D.B.H.[1]	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	2.2	1.6	1.3	1.3	1.8	1.5	2.1	1.8
2	48.5	32.4	36.9	42.5	39.1	31.6	45.7	39.2
3	293.0	202.7	299.9	332.0	253.8	188.2	290.8	245.7
4	406	287	460	486	371	260	419	353
5	508	365	603	610	485	327	540	458
6	577	419	701	683	571	373	628	538
7	1080	588	823	776	683	572	743	643
8	1190	720	893	818	755	656	815	714
9	793	675	864	545	632	488	747	586
10	579	509	617	378	455	361	555	422
11	436	395	458	272	340	275	424	315
12	337	316	352	202	261	214	331	242
13	267	259	276	153	205	171	264	191
14	215	218	222	119	165	138	215	154
15	178	188	181	94	134	114	177	126
16	149	165	150	75	111	95	147	104
17	126	148	127	61	93	80	124	88
18	108	136	108	51	79	68	106	75
19	94	127	93	42	68	59	91	65
20	82	120	81	35	59	51	79	56
21	73	115	71	30	51	44	69	49
22	65	112	63	26	45	39	60	43
23	59	110	56	22	40	34	53	39
24	54	109	51	19	36	31	47	34
25	64	120	70		33	28	62	32
26	59	119	63		30	26	56	29
27	55	119	58		28	24	51	27
28	51	120	53		26	22	46	25
29	48	121	49		24	21	42	24
30	46	123	45		23	20	38	22
31	44	125	42		21	18	35	21
32	42	127	39		20	17	34	19
33	40	129	37		19	16	34	18
34	39	132	34		18	15	33	17
35	38	131	32		17	14	33	16
36	37	130	30		16	14	33	15
37	36	129	29		15	13	34	15
38	36	128	27		14	12	34	14
39	35	127	26		14	12	35	13
40	35	126	24		13	11	36	12

TABLE 9--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	35	126	23		12	10	36	12
42	35	125	22		12	10	37	11
43	35	124	21		11	10	38	11
44	35	123	20		11	9	39	10
45	35	122	19		10	9	38	10
46	35	122	18		10	8	38	9
47	35	121	18		9	8	37	9
48	36	121	17		9	8	36	9
49	36	120	16		9	7	36	8
50	36	120	16		8	7	35	8
51	37	119	15		8	7	34	8
52	37	119	15		8	7	34	7
53	38	118	14		7	6	33	7
54	38	118	14		7	6	33	7
55	39	118	13		7	6	33	7
56	39	117	13		7	6	32	6
57	40	117	13		6	5	32	6
58	41	117	12		6	5	31	6
59	41	116	12		6	5	31	6
60	42	116	12		6	5	31	6
61	43					5	31	5
62	43					5	30	5
63	44					4	30	5
64	45					4	30	5
65	46					4	30	5
66	46					4	29	5
67	47					4	29	4
68	48					4	29	4
69	49					4	29	4
70	50					4	28	4
71	50					3		
72	51					3		
73	52					3		
74	53					3		
75	54					3		
76	55					3		
77	55					3		
78	56					3		
79	57					3		
80	58					3		

[1]ABOVE THE DASHED LINE, THE ENTIRE BOLE THAT IS >3 INCHES IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT THAT IS >3 INCHES IS INCLUDED.

[2] D F= DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

[3]OVENDRY WEIGHT.

TABLE 10--TOTAL WEIGHT OF RESIDUE PER SQUARE FOOT OF BASAL AREA BY D.B.H., OF FOLIAGE, BRANCHWOOD (LIVE AND DEAD), AND UNMERCHANTABLE TIP FOR AN 8-INCH UNMERCHANTABLE TIP

8-INCH TIP, TOTAL, BASAL AREA

	SPECIES[2]							
D.B.H.[1]	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
1	535.0	578.3	447.1	380.6	672.0	689.2	519.2	919.9
2	579.5	576.0	486.7	554.8	594.9	615.3	564.4	827.4
3	662.0	643.5	640.5	744.8	640.1	619.9	662.8	846.8
4	736	706	759	863	700	639	755	889
5	804	763	857	946	766	664	841	940
6	866	814	941	1010	833	691	923	997
7	1360	978	1040	1060	907	867	1010	1070
8	1450	1100	1080	1090	956	931	1060	1110
9	1040	1040	1030	806	818	748	990	966
10	815	862	774	630	627	608	789	785
11	660	732	605	506	498	506	650	655
12	552	639	490	422	409	432	552	563
13	475	571	408	363	344	378	480	496
14	417	521	348	320	297	337	427	446
15	374	483	303	288	260	305	385	406
16	341	454	269	264	232	280	353	375
17	314	431	241	245	210	259	328	350
18	293	413	220	231	192	242	308	330
19	276	399	202	219	177	228	291	312
20	262	387	188	209	165	216	277	298
21	251	378	176	201	154	206	266	285
22	241	370	166	195	146	198	256	275
23	233	364	157	189	138	190	248	265
24	226	359	150	185	132	184	241	257
25	236	366	168		133	185	256	257
26	229	361	160		128	180	248	250
27	224	357	154		123	175	242	244
28	219	354	147		119	171	236	239
29	214	352	142		115	167	231	234
30	211	349	137		112	163	227	229
31	207	347	133		109	160	223	225
32	204	346	129		106	157	220	221
33	202	344	125		103	154	217	218
34	199	343	122		101	151	214	215
35	197	342	119		98	149	211	212
36	195	341	116		96	146	209	209
37	193	341	113		94	144	207	206
38	192	340	111		92	142	205	204
39	190	340	109		90	140	203	202
40	189	339	107		89	139	201	200

TABLE 10--CONTINUED

D.B.H.[1]	SPECIES[2]							
	DF	PP	WL	LP	WP	WC	WH	GF
INCHES	POUNDS[3]							
41	188	339	106		89	138	200	199
42	187	337	105		88	137	198	199
43	186	336	104		87	136	197	198
44	185	335	103		86	136	196	198
45	184	335	102		86	135	195	198
46	183	334	101		85	135		197
47	183	333	100		84	134	193	197
48	182	332	99		84	134	192	197
49	181	331	98		83	133	191	197
50	181	331	98		83	133	190	197
51	180	330	97		82	133	189	197
52	180	330	96		82	132	188	197
53	179	329	96		81	132	188	197
54	179	329	95		81	132	187	197
55	179	328	95		81	132	187	197
56	178	328	94		80	131	186	197
57	178	327	94		80	131	185	197
58	178	327	93		80	131	185	197
59	177	326	93		79	131	184	197
60	177	326	93		79	131	184	197
61	177		92			131	183	198
62	177		92			130	183	198
63	176		92			130	183	198
64	176		91			130	182	198
65	176		91			130	182	199
66	176		91			130	182	199
67	176		90			130	181	199
68	176		90			130	181	200
69	175		90			130	181	200
70	175		90			130	180	200
71	175		89			130		
72	175		89			130		
73	175		89			130		
74	175		89			130		
75	175		89			130		
76	175		88			130		
77	175		88			130		
78	175		88			130		
79	175		88			130		
80	175		88			130		

[1]ABOVE THE DASHED LINE, THE ENTIRE BOLE IS INCLUDED IN THE WEIGHT ESTIMATES. BELOW THE DASHED LINE, THE UNMERCHANTABLE TIP WEIGHT IS INCLUDED. THE SOLID LINE CIRCUMSCRIBES THE FIELD DATA LIMITS, EXCLUDING THE UNMERCHANTABLE TIP.

[2]DF = DOUGLAS-FIR; PP = PONDEROSA PINE; WL = WESTERN LARCH; LP = LODGEPOLE PINE; WP = WESTERN WHITE PINE; WC = WESTERN REDCEDAR; WH = WESTERN HEMLOCK; GF = GRAND FIR.

[3]OVENDRY WEIGHT.

Table 11--Density of wood for selected western species1

Species	Density
CONIFERS	Pounds per cubic feet
Cedar:	
Western redcedar	20.0
Incense cedar	23.1
Alaska cedar	27.5
Douglas-fir:	
Coastal (Washington and Oregon)	30.0
Northern Rocky Mountains	30.0
Southern Rocky Mountains	28.7
Fir:	
Grand fir	23.1
California red fir	23.7
Noble fir	24.3
Pacific silver fir	26.8
White fir	24.3
Subalpine fir	20.0
Western hemlock	28.1
Western larch	32.4
Pine:	
Lodgepole pine	25.6
Ponderosa pine	25.0
Sugar pine	22.5
Western white pine	23.7
Redwood, old-growth	25.0
Spruce:	
Engelmann spruce	21.8
White spruce	25.0
Sitka spruce	25.0
HARDWOODS	
Quaking aspen	23.7
Black cottonwood	21.8
Golden chinkapin	26.2
Tanoak	41.6
Pacific madrone	40.3
California black oak	35.6

1Density values for golden chinkapin from Resch and Huang (1965); for tanoak, Schniewind (1960b); for Pacific madrone, Schniewind (1960a); California black oak, Markwardt and Wilson (1935); for the rest, USDA Forest Products Laboratory (1974).

ACCURACY

For a given species and d.b.h., crown weight per tree varies considerably within individual stands. We suspect that variation in crown weight per tree may vary as much within stands as it does between major forest regions. Thus, residue predictions may be about as accurate outside as within the study areas.

Accuracy of predictions can vary considerably, depending on species, stand conditions, stand density, and accuracy of the timber stand inventory. Sources of variation include the equations used for estimating live crown weight, dead crown weight, unmerchantable tip volume, and wood density: estimates of defect and breakage factors: and accuracy of tree inventory data.' The approximate half-width of the 67-percent confidence interval for live crown weight of an individual tree having mean d.b.h. expressed as a percent of the mean crown weight value for ponderosa pine is *36* percent: western larch, 38 percent: lodgepole pine ,22 percent: western white pine, 45 percent: western redcedar, 52 percent: and grand fir, 57 percent. These percentages were derived from Brown's (1978) data which were collected in western Montana and northern Idaho and had a d.b.h. range of approximately 1.0 to 35.0 inches. A study by the Forest Residues Program at the Pacific Northwest Forest and Range Experiment Station (see footnote 1, page 2) showed negligible difference between coastal and inland Douglas-fir and coastal and inland western hemlock live crown weight when this regression model was used:

$$\ln(w) = a + b \ln(d);$$

where:

w = live crown weight (pounds),
d = diameter breast height (inches), and
a and b = regression coefficients.

Based on this study, the live crown weights of trees east and west of the Cascade Range were considered the same for ponderosa pine, western larch, lodgepole pine, western white pine, western redcedar, and grand fir.

The Douglas-fir and western hemlock weights were derived from data collected from both the east and west sides of the Cascades. The d.b.h. range for western hemlock was approximately 1.0 to 46.0 inches and for Douglas-fir from approximately 1.0 to 87.0 inches. The approximate half-width of the 67-percent confidence interval for the live crown weight of an individual tree having mean d.b.h. expressed as a percent of the mean crown weight value is 89 percent for Douglas-fir and 68 percent for western hemlock. When weight is predicted for timber stands, errors for individual trees tend to balance out. Thus, estimates for stand averages are expected to be more accurate than estimates for individual trees.

A test to validate predictions was conducted in western Montana in three small stands, each dominated by a single species--ponderosa pine, Douglas-fir, or lodgepole pine. Crown weights were predicted before cutting. After cutting, the residue was intensively inventoried by the planar intersect method (Brown and Roussopoulos 1974). For residue less than 3-inch diameter, predicted weights were less than inventoried weights by 15, 22, and 37 percent of inventoried values. For all residue, predicted weights varied from 4 percent more to 15 percent less than inventoried weights. Some of the discrepancies were traced to biases in the test; thus, differences between predicted weights and actual weights should be less than indicated by our test.

The validation was done prior to skidding of any logs. This test was also repeated in a typical old-growth Douglas-fir and western hemlock stand (in the Detroit Range District, Willamette National Forest) after logging. Down woody material was intensively inventoried prior to harvesting and after the logs were skidded. A high-lead skidder was used. Because a portion of the limbs was removed from the area with the logs and small branchwood was crushed and buried in the soil and because of errors in both estimating procedures, the residue prediction overestimated by a factor of three for material less than 3 inches in diameter. This one test shows the influence of logging on the amount of residue left onsite. Local knowledge about a particular sale area, logger, and type of harvest can be used to adjust predicted weights. When residue estimates from standing trees are used, the predictions should be evaluated in relative terms. Compare areas and find out which ones are going to create the least residue and the most, and rank the other areas between them. The areas with the most potential residue should then be studied more carefuly to assure proper management. If fire assessment is made from estimates of residue from standing trees, the fire parameters should also be viewed on a relative basis.

This handbook is to be used west of the summit of the Cascade Range. Tables 3 and 8 of this handbook correspond to tables 3 and 7 of the Brown et al. (1977) handbook; if the tables in these handbooks are compared, noticeable difference in weights will be found for a given d.b.h. and species. For example, small trees in this handbook are heavier than those in Brown et al. (1977), and large trees lighter. These differences in weights are caused by (1) a paradoxical relationship between different regression functions used to obtain bole weight for small trees, (2) different height functions used in volume-to-weight calculations, and *(3)* significant differences in weight of dead branches between large coastal and inland trees.

Irrequlariti es are found in the ascending flow of weights in the enclosed tables, especially from one side of the dashed line to the other. These irregularities are caused by (1) changing regression functions, (2) a rapid loss of unmerchantable tip weight as d.b.h. increases relative to the rate of increase for branchwood weight, (3) changing from estimating entire bole weights plus crown above the dashed line to estimating just unmerchantable tip weights plus crown below the dashed line, and (4) inherent data variation and sampling error.

The noticeable difference in predicted weights for small trees between this handbook and those of Brown et al. (1977) and the irregularities support the thesis that predicted crown weights should be used on a relative basis, not an absolute basis.

Land managers should be aware that a noticeable difference may be found between predicted and actual loadings. The major causes of these differences are: (1) some limbs and unmerchantable tips are hauled out of the cutting unit; (2) small twigs and foliage are buried in the soil; (3) number of trees actually cut and trampled may be different than predicted; (4) cull and breakage left onsite are difficult to predict; and (5) because of local environmental conditions, trees from a given site may have noticeably different crown weights than trees sampled to derive the enclosed weight tables. Users of residue predictions should not become discouraged by these discrepancies between predicted and actual residue loadings; by inventorying postharvest down woody material (Brown 1974, Maxwell and Ward 1976), factors may be obtained that can be used to adjust future predictions. By following this procedure, land managers will soon develop confidence in their predictions,

FUEL APPRAISAL

Appraising potential fire behavior of fuels is often termed fuel appraisal and is the process of describing fuel characteristics, such as quantity and size, and interpreting the fuel in terms of fire behavior; for example, rate of spread, fireline intensity, and flame length, Thus, the appraisal process attempts to answer the question: What is the expected fire behavior for different fuels, given steepness of slope and weather conditions? The question is difficult to answer, partly because the answer is made up of different elements of fire behavior (Anderson 1974): rate of spread, intensity, crowning potential, spotting potential, and duration of heat. One or more of these elements may have to be appraised when a specific fuel management situation is being evaluated.

Potential fire behavior of downed woody debris can be appraised by mathematical modeling and experienced judgment, Mathematical modeling of rate of spread, fireline intensity, and flame length, for example, offers the most objective means of appraising potential fire behavior. This approach may not be readily available to some land managers, however.

Experienced judgment is an important means of appraising fuels because an experienced person can integrate many factors that elude quantification. Even when more sophisticated methods are available, judgment is still important. One way of using experienced judgment is to establish a reference (tons per acre) than can be used to compare with other fuel loadings. The reference loading should represent fuels for which a consensus of land managers experienced in control of fire determines the rating. Ratings, for example, might be for low, medium, or high fire intensity potential, or either acceptable or unacceptable regarding the ability of an initial attack crew to gain control. After a reference loading is set, fuels are appraised on a relative basis. For example, for material less than 3 inches in diameter, if a loading of 10 tons per acre is established as a reference, then a loading of 20 tons per acre would exhibit approximately twice the potential fire behavior.

How Much Fuel Is Acceptable?

Fire managers commonly want to know the tonnages of fuel that are acceptable; for example, to minimize potential fire danger. This question is difficult to answer because fire behavior depends not only on fire potential at one location but also on other factors, such as distribution of fuels and fire behavior potential over surrounding areas that may cover one or more drainages. Acceptable fuel loading depends on resource values, management objectives for the land, pattern of land ownership, and suppression capability. In some stands, acceptable loading depends on resistance of trees to crown scorch and cambium kill. Professional judgment is needed to determine acceptable fuel tonnages.

Decision steps.--To decide how much fuel is acceptable requires integration of many factors (fig. 3). This can be done systematically as follows:

1. Consider management objectives and values at risk. For the latter, resource values and risk of fires causing damage during a period of high fire danger are jointly considered.

2. Appraise fuels by (a) describing fuels from inventory and prediction; and (b) interpreting fire behavior potential, such as rate of spread, flame length, intensity, and scorch height.

3. Consider other fire-related factors, such as fuel and potential fire behavior on adjoining areas, suppression capability, frequency and severity of historical fires, and fire's ecological role.

Acceptable fuel loadings can depend to a high degree on factors in item 3. For example, a heavier fuel loading would be more acceptable on a unit surrounded by sparse fuels with little chance of ignition than on a unit surrounded by heavy fuels with a high chance of ignition.

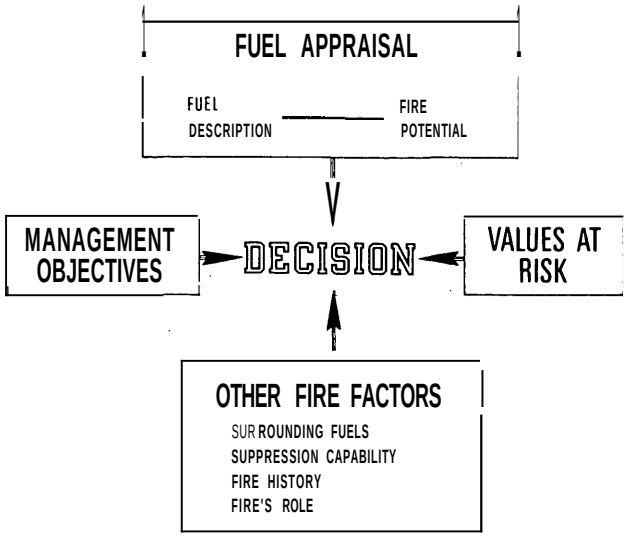

Figure 3.--Factors to consider when deciding how much fuel is acceptable.

Fuel loading standards.--No single fuel loading may be acceptable for a large administrative area. Herein lies the dilemma of setting fuel standards. Establishing standards would permit the setting of clear objectives for management of residue and provide benchmarks with which to measure accomplishments; however, standards could easily circumvent professional judgment for determining the maximum acceptable level of fuel for specific sites. One approach to determining acceptable fuel levels is to develop different standards for and evaluate each major decision for circumstances (fig. 3) encountered on a large administrative unit.

Even if fuel standards are set, the final decision on how much residue is acceptable should be coordinated among land management interests and their objectives.

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APPENDIX

The sources of the various functions used in making the weight estimates came from several investigators. For live branchwood (including foliage) weight of Douglas-fir and western hemlock., equations developed by the Forest Residues Program at the Pacific Northwest Forest and Range Experiment Station were used.[1] Hereafter, these two species will be referred to as the coastal species. For all other species, Brown's (1978) live branchwood (including foliage) weight equations are used for up to 40-inch d.b.h. At 40-inch d.b.h., a ratio was constructed between the weight of each species (except western hemlock) and the weight of coastal Douglas-fir.

$$Ri = \frac{SPPi}{DF};$$

where:

Ri = ratio of inland species weight to coastal Douglas-fir weight;

Sppi = species weight at 40-inch d.b.h.,

DF = coast Douglas-fir live branch weight at 40-inch d.b.h.; and

i = 1,...,5 species.

The ratios are shown in table 12.

Table 12--Ratios used to estimate the weight of species above 40-inch d.b.h.[1]

Species	Ratio	Range in d.b.h.
Ponderosa pine	1.95	41-60
Western larch	.54	41-60
Western white pine	.45	41-60
Western redcedar	.72	41-80
Grand fir	.99	41-70

[1]Coastal Douglas-fir is the base species.

[1]Predicting crown weight of Pacific Northwest Douglas-fir and western hemlock. Unpublished data on file at Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Weight of coastal Douglas-fir between 41- and 80-inch d.b.h. was then multiplied by each ratio for preliminary estimates for each species. Until more data become available, this approach should give reasonable estimates.

For estimating weight of dead branchwood of coastal Douglas-fir, the equation (see footnote 1 and table 13) is used over the entire d.b.h. range (1- to 80-inch d.b.h.) of the enclosed tables. For estimating dead branchwood of other species, Brown's (1978) functions were adjusted and used. The adjustment was a ratio between Brown's (1978) Douglas-fir dead weight and each of his other species. Since this ratio was not constant over Brown's (1978) data, several ratios covering each species d.b.h. range were calculated. The ratios were then regressed on d.b.h. for each species. These regression functions were then multiplied by the coastal Douglas-fir dead branchwood weight (DFDW) function for a prediction of dead branchwood weight. The regression functions for adjustment ratios multiplied by the DFDW are shown in table 13. Beyond Brown's (1978) data, the functions flattened and were considered reasonable to use up to the d.b.h. shown in the tables for each species.

Table 13--Ratios used to adjust Brown's (1978) inland dead branchwood functions to represent the dead branchwood for each coastal species

Species	Function 1
Coastal Douglas-fir dead weight	DFDW = 22.46 + 0.0010X + 0.2425Y 9.83 if d <9.8 X = d3 if d >9.8 Y = d^2 - 9.8' if d <c9.8 0 if d 79.8
Ponderosa pine	DW = (2.11 - 0.255 ln d) (DFDW)
Western larch	DW = 0
Lodgepole pine	DW = (1.927 - 1.839d-1.5567) (DFDW)
Western white pine	DW = (0.992 - 0.211 ln d) (DFDW)
Western redcedar	DW = (0.97) (CDFDW)
Western hemlock	DW = (0.071 + 0.094 ln d) (DFDW)
Grand fir	DW = (0.253 + 0.631 ln d) (DFDW)

lDFDW = coastal Douglas-fir dead branchwood weight; d = d.b.h. in inches; DW = dead branchwood weight.

Entire bole weights are estimated for trees listed above the dashed line in the tables. The boles were estimated by Faurot's (1977) total cubic-foot volume equations and converting them to weight by multiplying by the wood density of the appropriate species. Faurot (1977) studied ponderosa pine, lodgepole pine, western larch, and Douglas-fir. For other species, the Douglas-fir function was used.

Unmerchantable tip weights for trees between 6- and 24-inch d.b.h. were calculated from Faurot's (1977) equations for the unmerchantable tip. Faurot's (1977) equations for volume of unmerchantable tips and boles required d.b.h. and height as independent variables. For constructing the tables, height was estimated. For trees less than 8-inch d.b.h., height equations by Brown et al. (1977) were used; for trees above 8-inch d.b.h., the equations in table 14 were used. Data from Hartman2 and Woodfin3 were used to develop the equations in table 14.

Table 14--Height equations for estimating tree height (feet) for trees larger than 8-inch d.b.h.

(Model: height = a + b (d.b.h.)c)

Species	Regression coefficients			Standard error	Observations	Range in d.b.h.
	a	b	c			
				Feet		Inches
Douglas-fir1	-30.3241	50.0770	0.3991	17.49	506	7-93
Douglas-fir2	-331.673	306.57'4	0.1346	25.07	729	10-90
Grand fir	454.834	-699.662	-0.2649	14.60	20	10-37
Shasta fir	342.965	-696.633	-0.3772	'11.36	63	12-53
Silver fir	31.4377	8.9200	0.7603	14.60	39	7-28
White fir	39.2434	6.1657	0.8414	10.57	151	7-47
Ponderosa pine	261. 338	-458.831	-0.4008	14.90	23	10-40
Sugar pine	60.6938	3.9472	-0.8756	11.02	28	10-65
Western hemlock	1295.92	-1379.27	-0.0577	16.3	355	7-52
Incense-cedar1	4645.09	-4728.41	-0.0162	16.2	45	12-60
Incense-cedar2	3595.10	-3657.50	-0.0174	14.7	371	10-58
Port-Orford-cedar	1153.17	-1266.09	-0.0751	14.6	3'9	10-67
Western redcedar	-301.283	269.106	0.1427	13.5	71	10-48

1Data from western Oregon.

2Data from'western Washington.

2Hartman, George. U.S. Department of the Interior, Bureau of Land Management, Oregon: State Office, Portland, Branch of Forestry, Research and Biometrics Section.

3Woodfin, Richard O., USDA Forest Service? Pacific Northwest Forest and Range Experiment Station, Portland, Oreqon.

Beyond 24-inch d.b.h., which corresponds to the end of Faurot's (1977) data, a geometric approach was used to estimate weight of the unmerchantable tip. The formula used to estimate length of the unmerchantable tip for large trees is shown below.4.

$$T = \frac{D\ L'\ (1-A)}{1 - DA};$$

where:

T = tip length (ft),

$$D = \frac{DIBt}{DIB\ 16},$$

DIBt = merchantable top diameter inside bark (in),

DIB16= (Girard form class)5 *DBH,

DBH = diameter breast height (in), and

A = values used to adjust tree taper by species and d.b.h. The values used were developed by Hartman (see footnote 2) and are shown in table 15.

L'= Total height - 16 feet for butt log.

Table 15--"A" values used to estimate weights of unmerchantable tips for trees greater than 24-inch d.b.h.

Species	"A" constants1
Ponderosa pine and Douglas-fir	A = 0.615 - 0.00225 * d
Grand fir, western hemlock, and western white pine	A = 0.558 - 0.00225 * d
All other species	A = 0.451

1d = d.b.h. in inches.

4Rearrangement of the hyperbola formula as defined by Behre (1927).

5For our tables, a Girard form class of 0.72 was used.

The tip length was then put into a paraboloid formula and multiplied by density to change volume to weight:

$$TW = \left(\frac{d^2 T}{8}\right) (DEN);$$

where:

TW = tip weight (lb),
d = merchantable top diameter inside bark (ft); and
DEN = wood density of species (lb/ft^3).

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DIB16= (Girard form class)5 *DBH,

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5For our tables, a Girard form class of 0.72 was used.

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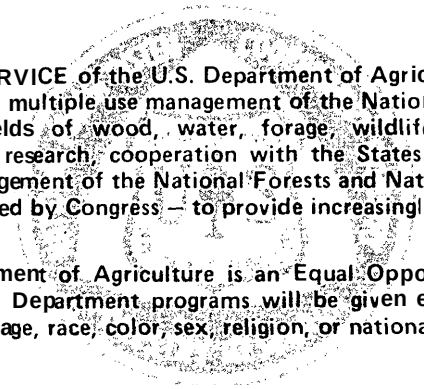

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