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Forest Service Handbook 2409.12 – Timber Cruising Handbook

Chapter 80 – Weight Factor Determination

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Responsible Staff: Forest Management, Rangelands Management, and Vegetation Ecology (FMRMVE)

Explanation of changes: Following is an explanation of the changes throughout the directive by section.

Section 81: Moved language dealing with weight scaling to FSH 2409.11a, Cubic Scaling, Chapter 30, Weight Scaling.

Section 82.2: Removed outdated section on the Xylodensimeter. Renumbered all proceeding chapters.

Section 82.23: Added the use of shipping scales.

Section 82.3: Added Disk Scaling procedures.

Section 85: Added section on moisture content of wood.

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81 - Weight to Volume Factors

81.1 - Documenting Weight Factors

The weight factor for a forest product may change by species, geographic location (latitude, aspect, elevation, site), live/dead, product, harvesting practices (how long the material remains in the woods after felling), tree age, season, climatic conditions, and probably many other factors. For 100 percent weight scaling, the intent is to use a factor that represents a reasonable average of the weight factors encountered during the life of a timber sale or group of timber sales. The Regional or Forest Measurement Specialist, based on experience, field data, and the value of material being sold, shall determine the proper weight factor for any situation.

As a minimum, weight factors must be specific to a species or species groups. Each weight factor used when processing a timber cruise must be documented in the sale folder. As a minimum, the documentation must include the weight factor, the source of the weight factor, and the material to which the factor will be applied.

82 - The Development of Weight to Volume Factors

Regardless of the method used to determine a weight factor, if data is collected, the following standards must be met for each weight factor. There must be a minimum of 10 observations and the sampling error for the calculated factors must be 15 percent or less at the 95 percent confidence level. An observation is defined as either a load of logs or an individual tree.

Acceptable procedures for the development, validation, and use of weight factors for the sale of forest products are illustrated in section 82.1. If a procedure not described in this handbook is used, it must be documented and approved by the Regional Forester.

82.1 - Traditional Log Scaling

This method uses information for completed traditional scaled sales (historical information). To use this method, the following information must be available by load:

1. Species and product composition by load.

2. Gross cubic volume by load (volume determined by truck scale is not acceptable for this procedure). Board foot volumes are not acceptable.

3. Net load weight (this is the gross weight minus the tare weight, or the weight of the empty truck subtracted from the weight of the loaded truck).

4. Sale location.

As a minimum, a separate weight factor is calculated for each species or species group. To use historical scale information, all loads must be single species or species group. A load is considered single species if 95 percent of the load volume is from a single species.

Consider each load as a separate observation. An average weight factor is calculated by dividing the sum of the net load weight for all loads by the sum of the gross cubic volume for all loads.

$$WtFac = \frac{\sum_{i=1}^{n} NetWt_i}{\sum_{i=1}^{n} GrsVol_i}$$

Where:

$NetWt_i$ = The net weight for the i^{th} load.
$GrsVol_i$ = The total gross volume for the i^{th} load.

The sampling error is calculated using the individual load information. The sampling error for the weight factor is computed using the formula described below:

$$E = \left(\frac{SE}{WtFac}\right) \times 100 \times t$$

Where:

E = Sampling error.
n = Sample size.
t = Student's t-distribution.

$$SE = Standard\ Error = \frac{SD}{\sqrt{n}}$$

$$SD = Standard\ Deviation$$

$$= \sqrt{\left(\frac{1}{\overline{GrsVol}^2}\right)\left(\frac{\sum_{i=1}^{n} NetWt_i^2 + WtFac^2 \sum_{i=1}^{n} GrsVol_i^2 - 2 \times WtFac \sum_{i=1}^{n}\left(NetWt_i \times GrsVol_i\right)}{(n-1)}\right)}$$

$$\overline{GrsVol} = Mean\ Gross\ Volume = \left(\frac{\sum_{i=1}^{n} GrsVol_i}{n}\right)$$

To calculate the sample size needed to achieve a specific sampling error, use the following equation:

$$n = \left(\frac{t^2 \times CV^2}{E^2}\right)$$

Where:

$$CV = Coefficient\ of\ Variation = \left(\frac{SD}{WtFac}\right) \times 100$$

An example of calculating weight factors using the traditional log scaling method is provided in exhibit 01.

82.1 - Exhibit 01

Traditional Log Scaling

Load	GrsWt	TareWt	NetWt	Spec	Prod	GrsVol	NetWt²	GrsVol²	NetWt*Grs Vol
11150	69780	26320	43460	A	1	1067.1	1888771600	1138702.4	46376166
11151	63800	25360	38440	A	1	990.8	1477633600	981684.6	38086352
11152	71020	26280	44740	A	1	1035.0	2001667600	1071225.0	46305900
11153	65840	25400	40440	A	1	766.2	1635393600	587062.4	30985128
11154	69600	26420	43180	A	1	946.6	1864512400	896051.6	40874188
11155	66100	26340	39760	A	1	956.0	1580857600	913936.0	38010560
11156	70180	25420	44760	A	1	1268.1	2003457600	1608077.6	56760156
11157	64480	26320	38160	A	1	962.5	1456185600	926406.3	36729000
11158	71550	26450	45100	A	1	1372.5	2034010000	1883756.3	61899750
11159	67410	25890	41520	A	1	945.1	1723910400	893214.0	39240552
Total			419560			10309.9	17666400000	10900116.2	435267752

Calculate weight factor for Species A using information in exhibit 01, Traditional Log Scaling:

$$WtFac = \frac{\sum NetWt}{\sum GrsVol} = \frac{419560}{10309.9} = 40.69$$

Determine the sampling error for the data shown in exhibit 01, Traditional Log Scaling:

$$\overline{GrsVol} = \left(\frac{\sum_{i=1}^{n} GrsVol_i}{n} \right) = \left(\frac{10309.9}{10} \right) = 1031.0$$

$$SD = \sqrt{\left(\frac{1}{\overline{GrsVol}^2} \right) \left(\frac{\sum_{i=1}^{n} NetWt_i^2 + WtFac^2 \sum_{i=1}^{n} GrsVol_i^2 - 2 \times WtFac \sum_{i=1}^{n} (NetWt_i \times GrsVol_i)}{(n-1)} \right)}$$

$$= \sqrt{\left(\frac{1}{1031.0^2} \right) \left(\frac{17666400000 + (40.69)^2 (10900116.2) - 2(40.69)(435267752)}{(9)} \right)}$$

$$= 5.5196$$

$$SE = \left(\frac{SD}{\sqrt{n}}\right) = \left(\frac{5.5196}{\sqrt{10}}\right) = 1.7455$$

$$E = \left(\frac{SE}{WtFac}\right) \times 100 \times t = \left(\frac{1.7455}{40.69}\right) \times 100 \times 2.26 = 9.69$$

Using the SD and the mean gross volume given above, determine the number of samples needed to achieve a 5 percent sampling error with a 95 percent confidence (t = 2).

$$CV = \left(\frac{SD}{WtFac}\right) \times 100 = \left(\frac{5.5196}{40.69}\right) \times 100 = 13.565$$

$$n = \left(\frac{t^2 \times CV^2}{E^2}\right) = \left(\frac{(2)^2 \times (13.565)^2}{(5)^2}\right) = 30$$

82.11 - Special Studies

Traditional log scaling may be used on active sales to determine weight factors in the same way historical information is used from completed scaled sales. A number of single species loads will be selected for traditional scaling and weighing from an active sale where load weight is available. The sale can either be a sample weight or a 100 percent scaled sale. The data can also be collected as a special study from a sale sold as tree measurement providing an adequate location for log rollout is identified, certified scalers and cubic scaling rules are used to determine load volume, and certified weight scales are used to determine net load weight. (Note: The measured gross cubic volume for all logs on each selected load must be used to determine load volume. Loads may not be subsampled for volume determination when developing a volume to weight factor.)

To use this method, consider the following for each load:

1. Each load must be single species or species group.

2. A load is considered single species if 95 percent of the load volume is from a single species.

3. Each load will be considered a separate observation.

An average weight factor is calculated by dividing the total net load weight for all loads by the total gross cubic volume for all loads. The sampling error is calculated using the individual load information (see sec. 82.1, ex. 01).

82.2 - Chunk Scaling

Chunk scaling is a destructive sampling process and refers to scaling and weighing pieces, or chunks, of a tree in a field setting. This procedure was developed to allow local units to develop or validate weight factors as necessary with minimal equipment, personnel, and dollar expenditures. Unlike the traditional load scaling procedures, chunk scaling does not require special scaling facilities, motorized equipment to manipulate logs, certified production scalers, or weight scales certified for commercial transactions.

Chunk scaling requires a set of field procedures be followed to select the chunks, and all measurements be taken by someone with at least a Utilization Scaling Certification. There are two accepted sets of field procedures for selecting the chunks within each tree—the large chunk procedure (described in sec. 82.31) and the small chunk procedure (described in sec. 82.32). The end diameters of each chunk are determined by the procedure specified in the Cubic Scaling Handbook (FSH 2409.11a, sec. 21.3) with diameters being recorded to the nearest 10^{th} of an inch or the nearest 100^{th} of a foot, depending on the measuring device being used. Chunk length must not exceed 8 feet in length for weight studies (the taper, or change in taper rates for pieces longer than 8 feet can distort the cubic volume for the chunk resulting in a distorted weight factor for the piece). The length of a chunk is recorded to the nearest 100^{th} of a foot. If the chunk was not cut square, measurements are taken on both the short and long sides and averaged. Cubic volume for the chunk is calculated using the Smalian formula and recorded to the nearest 100^{th} of a cubic foot. The chunk weight is recorded to the precision of the weight scale being used.

The weight of all chunks and volume of all chunks are summed for each tree, and each tree is considered to be a single observation, not each chunk. An average weight factor for the population is calculated by dividing the total weight for all trees by the total gross cubic volume for all trees.

$$WtFac = \frac{\sum_{i=1}^{n} TrWt_i}{\sum_{i=1}^{n} TrVol_i}$$

Where:

$TrWt_i$ = Sum of the chunk weights for the i^{th} tree.
$TrVol_i$ = Sum of the chunk volumes for the i^{th} tree.

The sampling error is calculated using the sum of the weights and volumes for individual trees using the following formula:

$$E = \left(\frac{SE}{WtFac}\right) \times 100 \times t$$

Where:

E = Sampling error.
n = Sample size.
t = Student's t-distribution.

$$SE = Standard\ Error = \frac{SD}{\sqrt{n}}$$

$$SD = Standard\ Deviation$$

$$= \sqrt{\left(\frac{1}{\overline{TrVol}^2}\right)\left(\frac{\sum_{i=1}^{n} TrWt_i^2 + WtFac^2 \sum_{i=1}^{n} TrVol_i^2 - 2 \times WtFac \sum_{i=1}^{n} (TrWt_i \times TrVol)_i}{(n-1)}\right)}$$

$$\overline{TrVol} = Mean\ Tree\ Volume = \left(\frac{\sum_{i=1}^{n} TrVol_i}{n}\right)$$

To calculate the sample size needed to achieve a specific sampling error, use the following equation, rounding up to the next whole number:

$$n = \left(\frac{t^2 \times CV^2}{E^2}\right)$$

Where:

$$CV = \left(\frac{SD}{WtFac}\right)$$

The recommended data to record for a study are:

1. Procedure used to identify chunks.

2. Sale and/or location name (plot or unit number), location, and date of study.

3. For each tree: species, DBH, and total height.

4. For each chunk: chunk number, large end diameter (LED) and small end diameter (SED) in inches, and length in feet. Chunk volume is calculated in cubic feet using its SED, LED, and length. Chunk weight is recorded in pounds.

5. Additional information may be collected.

An example of the chunk scaling method is provided in exhibit 01. The data in the exhibit was collected using the large chunk procedure. The calculations are the same if the small chunk procedure is used to collect the data.

82.2 – Exhibit 01

Chunk Scaling

Aspen Species

Tree	#Chunks	TrWt (lb)	TrVol (cf)	$TrWt^2$	$TrVol^2$	TrWt*TrVol
1	9	1236.0	32.9	1527696.0	1082.4	40664.4
2	7	1254.8	23.8	1574523.0	566.4	29864.2
3	5	326.4	7.5	106537.0	56.3	2448
4	8	1729.3	36.4	2990478.5	1325.0	62946.5
5	5	643.0	12.8	413449.0	163.8	8230.4
6	8	1411.8	29.0	1993179.2	841.0	40942.2
7	5	955.5	18.0	912980.3	324.0	17199
8	7	655.4	25.3	429549.2	640.1	16581.6
9	7	377.0	9.5	142129.0	90.3	3581.5
10	7	1124.4	41.0	1264275.4	1680.8	46098.2
11	5	925.6	34.6	856735.4	1197.2	32025.8
12	6	915.6	30.6	838323.4	936.4	28017.4
13	5	344.6	11.1	118749.2	123.2	3825.1
14	8	1902.6	59.3	3619886.8	3516.5	112824.2
15	7	422.8	17.0	178759.8	289.0	7187.6
Total		14224.8	388.8	16967251.2	12832.4	452436.1

Calculate the weight factor for aspen using the data in exhibit 01, Chunk Scaling:

$$WtFac = \frac{\sum_{i=1}^{n} TrWt_i}{\sum_{i=1}^{n} TrVol_i} = \frac{14224.8}{388.8} = 36.59$$

$$SD = \sqrt{\left(\frac{1}{\overline{TrVol}^2}\right)\frac{\sum_{i=1}^{n} TrWt_i^2 + WtFac^2 \sum_{i=1}^{n} TrVol_i^2 - 2 \times WtFac \sum_{i=1}^{n}\left(TrWt_i * TrVol_i\right)}{(n-1)}}$$

$$= \sqrt{\left(\frac{1}{(25.9)^2}\right)\left(\frac{16967251.2 + (36.59)^2(12832.4) - 2 \times (36.59)(452436.1)}{(14)}\right)}$$

$$= 10.51$$

Calculate the sampling error for the data shown in exhibit 01, Chunk Scaling:

$$\overline{TrVol} = \left(\frac{\sum_{i=1}^{n} TrVol_i}{n}\right) = \left(\frac{388.8}{15}\right) = 25.9$$

Using the SD and the mean gross volume given above, determine the number of samples needed to achieve a 10 percent sampling error with a 95 percent confidence (t = 2).

$$CV = \left(\frac{SD}{WtFac}\right) \times 100 = \left(\frac{10.51}{36.59}\right) \times 100 = 28.72$$

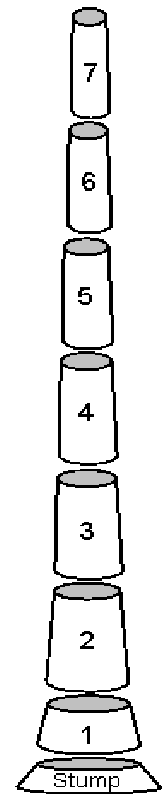
$$n = \left(\frac{t^2 \times CV^2}{E^2}\right) = \left(\frac{(2)^2 \times (28.72)^2}{(10)^2}\right) = 33$$

$$SE = \left(\frac{SD}{\sqrt{n}}\right) = \left(\frac{10.51}{\sqrt{15}}\right) = 2.71$$

$$E = \left(\frac{SE}{WtFac}\right) \times 100 \times t = \left(\frac{2.71}{36.59}\right) \times 100 \times 2.14 = 15.85$$

82.21 - Large Chunk Procedure

The large chunk procedure involves calculating a cubic volume for the entire merchantable bole of the tree and weighing the entire merchantable bole plus other portions of the tree that will be removed from the sale area. The first chunk will be from stump to DBH. The second chunk will be from DBH to 8 feet up the tree bole. The remaining tree bole will be bucked in 8-foot sections to the merchantable top. If a weight factor for only wood fiber is of interest, weigh only the portions of the tree bole that are scaled. If a total biomass weight factor is desired, weigh the total tree, including limbs and needles. An example of collecting data using the large chunk procedure is shown in exhibit 01.



Using this procedure on larger trees, 8- to 30-inches DBH, a field crew of 3 to 4 individuals can expect to average 10 trees per day.

82.21 – Exhibit 01

Chunk Scaling with Large Chunks

Aspen Species, Plot 1, Tree # 2

Chunk	Length (ft)	SED (in)	LED (in)	Chunk Wt (lbs)	Chunk Vol (cf)
1	4.10	11.0	12.5	165.8	3.1
2	8.10	10.6	11.0	274.0	5.2
3	8.15	9.9	10.6	242.2	4.7
4	8.00	9.0	9.9	193.0	3.9
5	8.15	7.7	9.0	168.6	3.1
6	8.10	6.5	7.7	123.0	2.2
7	8.05	5.0	6.5	88.2	1.5
Total				1254.8	23.7

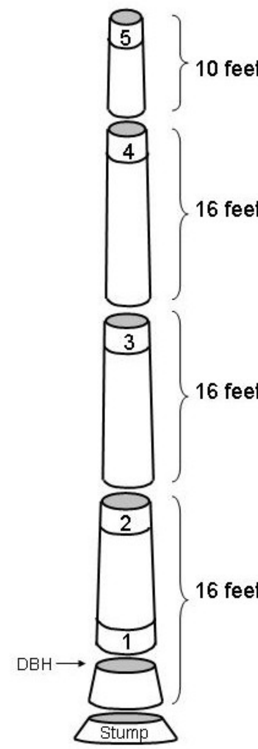
Where:

SED = Chunk small end diameter in inches.
LED = Chunk large end diameter in inches.

82.22 - Small Chunk Procedure

The small chunk procedure involves calculating a cubic volume for small chunks of the merchantable bole of the tree and weighing only those chunks. Using this procedure, every chunk is the same length. Chunk length may vary from study to study but must remain constant for all trees in a study. A recommended segment length is 2 feet but based on the tree sizes in the study and available equipment, a different length may be selected. The length selected should not result in segments that are too heavy to handle safely in the field with the available equipment.

This procedure gives more importance to the lower portion of the tree, where the majority of the volume is. First, determine the number and length of logs in the merchantable bole using segmentation rules appropriate for the Region. Select chucks from each log using the following procedure. The first chunk is a section 2 feet long (or chosen section length) with the large end of the chunk at DBH. The next chunk is a 2-foot section (or chosen section length) with the small end at the top of the first log. The next section is a 2-foot section (or chosen section length) with the small end at the top of the second log. This process is repeated for the merchantable bole of the tree. After each chunk is bucked out, it is re-measured to determine the actual length and end diameters. An example of collecting data using the small chunk procedure is shown in exhibit 01.



Using this procedure on larger trees, 8 to 30 inches DBH, a field crew of three to four individuals can expect to average 20 trees per day.

82.22 – Exhibit 01

Chunk Scaling with Small Chunks

Chunk	Length (ft)	SED (in)	LED (in)	Chunk Wt (lbs)	Chunk Vol (cf)
1	2.02	12.6	12.9	107.4	1.8
2	1.97	10.5	11.2	79.0	1.3
3	1.97	9.6	9.6	58.4	1.0
4	2.00	7.1	7.3	36.6	0.6
5	1.98	5.0	5.4	22.6	0.3
Total				304.0	5.0

Where:

SED = Chunk small end diameter in inches.
LED = Chunk large end diameter in inches.

82.23 - Equipment

Depending on the chunk selection procedure used, different equipment may be necessary. When dealing with chunks weighing 80 pounds or less, it is usually possible for the field crew to lift the chunks and either place them on a scale or suspend them from a scale. For chunks weighing 100 to 500 pounds, a mechanical lifting device (such as a chain pulley) must be used. Do not attempt to lift chunks over 500 pounds in a woods setting. Regional measurement specialists can provide guidance on selecting mechanical lifting devices for use.

For determining the weight of chunks, any scale that is certified for commercial transactions is acceptable. Scales certified for commercial transactions tend to be expensive, heavy, and may require special setup procedures. Scales not certified for commercial transactions are acceptable, if they can be shown to produce consistent results for repeated weighing of the same object and have been tested against scales of known accuracy. As a minimum, the scale must be easily read in half pound increments.

Scale can be suspended from an angle bracket strapped to a tree, from a heavy-duty tripod, or from a receiver mounted hitch.

For small chunks, the digital shipping scale can be used to determine the chunk weight. The scale is placed on a piece of plywood board on the ground. The chunks can be lifted or rolled on the scale.

82.24 - Tree Selection Procedures

Sample trees should cover the range of size classes and products, by species, which will be sold. In addition, if the trees of interest are other than normal healthy trees, fire salvage for example, then trees should be selected to cover the range of damage present in the sale area.

82.3 - Disk Scaling

Disk scaling is a destructive sampling process and refers to scaling and weighing thin disks (about 1 inch thick) of a tree in a field setting. This procedure was developed to allow local units to develop or validate green and dry weight factors as necessary with minimal equipment, personnel, and dollar expenditures. This method is similar to chunk scaling, but not damaging to the merchantability of the felled tree.

Disk scaling requires at least three disks cut from the felled tree: one from the stump, one from the merchantable top, and one from the middle at a log bucking point closest to the middle of the merchantable portion of the tree. More disk samples could be taken from the top of each log. The disk green weight is recorded in the field by using a small portable scale typically used to weigh shipping packages. The disk wood volume is obtained either by water displacement method (wood only) or by measuring the disk surface area and thickness. The measurement is

obtained with the average of two inside bark diameter measurements (perpendicular to each other) and average of four disk thickness measurements. The measurement can be taken in the field or in the laboratory. The disk diameters and thickness are recorded to the nearest 100th of an inch. The disk dry weight is obtained by the oven-dry method (221°F for 12 hours).

$$DiskVol = DiskDia^2 * DiskThick * 0.0004545$$
$$DiskWtFac = \frac{DiskWt}{DiskVol}$$

Where:

$DiskVol$ = disk wood cubic foot volume
$DiskDia$ = disk average inside bark diameter in inches
$DiskThick$ = average disk thickness in inches
$DiskWt$ = disk weight (wood and bark) in pounds
$DiskWtFac$ = weight to volume factor (lb/cf) for the disk

Each tree is considered to be a single observation, not each disk. The weight factor for each tree is the average of disk weight factor weighted by disk diameter squared.

$$TreeWtFac = \frac{\sum_{i=1}^{n} DiskDia_i^2 * DiskWtFac_i}{\sum_{i=1}^{n} DiskDia_i^2}$$

Where:

n = number of disk samples on the tree
$DiskDia_i^2$ = the square of the ith disk average diameter
$DiskWtFac_i$ = weight to volume factor of ith disk
$TreeWtFac$ = the weight factor for the sample tree

An average weight factor for the population is calculated by averaging tree weight factor weighted by DBH squared for all trees.

$$WtFac = \frac{\sum_{i=1}^{N} DBH_i^2 * TreeWtFac_i}{\sum_{i=1}^{N} DBH_i^2}$$

Where:

N = number of sample trees.
DBH_i = the DBH of ith tree
$TreeWtFac_i$ = the weight factor of ith tree
$WtFac$ = the average weight factor for the population

The sampling error is calculated using the following formula:

$$E = \left(\frac{SE}{WtFac}\right) * 100 * t$$

Where:

E = Sampling error.
n = Sample size.
t = Student's t-distribution.

$$SE = Standard\ Error = \frac{SD}{\sqrt{N}}$$

$$SD = Standard\ Deviation = \sqrt{\frac{\sum_{i=1}^{N} DBH_i^2 * (TreeWtFac_i - WtFac)^2}{\frac{(N-1)\sum_{i=1}^{N} DBH_i^2}{N}}}$$

To calculate the sample size needed to achieve a specific sampling error, use the following equation, rounding up to the next whole number:

$$n = \left(\frac{t^2 * CV^2}{E^2}\right)$$

Where:

$$CV = \left(\frac{SD}{WtFac}\right)$$

82.31 - Disk Procedure

The disk procedure involves calculating a cubic volume for disks of the tree and weighing only those disks. Disk thickness may vary from study to study. A recommended thickness is about one inch. This procedure gives more importance to the lower portion of the tree and large DBH of the sample trees. The first disk is from the stump and the last disk is from the merchantable top. Then at least one disk is taken between the stump and the merchantable top, optionally one from the top of each merchantable log. After each disk is cut out, its diameters and thickness are measured to determine the disk volume and its green weight is weighed in the field. An example of collecting data using the disk procedure is shown in exhibit 01.

82.31 – Exhibit 01

Recording Weight Data Using Disk Procedure

Table 1. Disk Data of a Sample Tree

Sitka spruce, R10 Edna Bay, Tree # 1_10

Disk	DiskDia (in)	DiskThick (in)	DiskWt(lbs)	DiskVol (cf)	DiskWtFac	DiskDia^2	DiskWtFac*DiskDia^2
1	11.65	1.07	3.07	0.066004	46.49	135.7225	6309.74
2	7.95	0.79	0.97	0.022693	42.74	63.2025	2701.27
3	6.45	0.77	0.72	0.014559	49.45	41.6025	2057.24
Total						240.53	11068.25

Where:

DiskDia^2 = the square of the DiskDia.
DiskVol = DiskDia^2 * DiskThick * 0.0004545
DiskWtFac = DiskWt/DiskVol

TreeWtFac = $\frac{11068.25}{240.53}$ = 46.0

82.31 – Exhibit 01—Continued

Recording Weight Data Using Disk Procedure

Table 2. Sample Tree Data for Disk Scaling

Sitka spruce, R10 Edna Bay

Tree	DBH	TreeWtFac	DBH^2	TreeWtFac*DBH^2
1_10	9.7	46.0	94.09	4328.14
3_13	13.4	58.3	179.56	10468.35
4_27	27.2	40.6	739.84	30037.50
5_24	24.2	47.3	585.64	27700.77
7_12	12.5	61.4	156.25	9593.75
9_11	11.1	40.7	123.21	5014.65
11_18	18.2	46.2	331.24	15303.29
12_14	13.9	49.2	193.21	9505.93
18_21	20.8	45.6	432.64	19728.38
19_19	19.4	53.2	376.36	20022.35
100_25	24.9	55.4	620.01	34348.55
102_28	27.7	52.4	767.29	40206.00
103_23	23.0	40.3	529.00	21318.70
104_19	18.7	42.8	349.69	14966.73
105_20	20.0	49.2	400.00	19680.00
203_17	17.3	34.6	299.29	10355.43
204_22	21.6	39.3	466.56	18335.81
205_14	14.3	51.2	204.49	10469.89
206_16	16.6	46.9	275.56	12923.76
207_26	26.0	41.4	676.00	27986.40
212_19	18.8	46.0	353.44	16258.24
214_24	24.1	47.6	580.81	27646.56
216_16	15.7	50.7	246.49	12497.04
218_17	16.6	46.7	275.56	12868.65
219_23	23.0	40.5	529.00	21424.50
226_12	12.0	39.5	144.00	5688.00
Total			9929.23	458677.38

$$\text{WtFac} = \frac{458677.38}{9929.23} = 46.2$$

83 - Published Tables for Weight to Volume Factors

All published tables must be approved by the Regional Forester prior to use. To utilize a weight factor from a published table, knowledge of how the table was developed is required. There are many different procedures for determining a weight to volume factor, so it is important to identify the procedures used to determine whether or not a published table is applicable for a given sale. The following information should be easily obtained from the methods section of the publication, and should be noted along with other regional considerations:

1. Was bark included in the weight?
2. Did the weight of the material include non-merchantable material (tops, limbs, foliage)?
3. Was the material forced to a specific moisture content (oven dried) prior to weighing?
4. How was the cubic volume of the material determined?
5. Was the table developed for a specific size or type of material?
6. Have the tables been validated for local conditions?

84 - Using Weight Factors When Processing the Timber Cruise

There are many methods for estimating the weight of an individual tree or forest product on a given area of land. The procedures described in section 82 are intended to be compatible with traditional Forest Service practices for cruising and appraising forest products.

Once a weight factor is developed for a specific species and product, it is applied to the estimated cubic volume for all cruised trees of that species and product. This will provide a weight estimate, in pounds, for those trees. Weight factors are in terms of pounds per gross cubic foot and are applied to the estimated gross volume of the cruised trees.

In addition to weight factors, a percentage estimate is made for the amount of standing material that will be removed from the sale area. This is the amount of material that will cross the scales in a weight sale. The weight factor and the estimated percent removed are used to provide an estimate, from the cruise data, of the weight of material that will be removed from a sale area in pounds. To estimate total tons removed from the sale area, divide the weight estimate in pounds by 2000 (pounds per ton).

During the timber cruise, estimates of tree defect are made so the net cubic volume can be estimated. This net cubic volume is used in the appraisal process to determine the value of the sale. Using the appraised sale value and the estimate of the weight of material to be removed in tons, a price per ton can be calculated. An example can be seen in exhibit 01. For 100

percent weight sales, the cruise design should use the same sampling error standards as specified in section 41.1 for scaled sales.

84 – Exhibit 01

Determining Tons Removed and $/Tons

Table 1: Determining Estimated Tons Removed

Spec.	Prod.	Weight Factor	Gross Cubic	Estimated % Removed	Gross Cubic Removed[1]	Est. Pounds Removed[2]	Est. Tons Removed[3]
A	01	44.37	4663	95	4429.9	196554.7	98.3
B	01	62.78	5111	95	4855.5	304828.3	152.4
C	01	58.46	3820	95	3629.0	212151	106.1

[1]Gross Cubic Removed = Gross Cubic * Estimated % Removed.
[2]Est. Pounds Removed = Gross Cubic Removed * Weight Factor.
[3]Est. Tons Removed = Est. Pounds Removed/2000. (2000 lbs/ton).

Table 2: Determining Dollar per Ton for Each Species

Spec.	Prod.	Gross CCF	Net CCF	$/CCF	Value($)[1]	Est. Tons Removed[2]	$/Ton[3]
A	01	46.63	42.95	80.00	3436.00	98.3	34.95
B	01	51.11	45.32	40.00	1812.80	152.4	11.89
C	01	38.20	35.14	70.00	2459.80	106.1	23.18

[1]Value ($) = Net CCF * $/CCF.
[2]Est. Tons Removed = Est. Tons Removed from Table 1.
[3]$/Ton = Total Value ($)/Est. Tons Removed.

Table 3: Determine Average Dollar per Ton for the Sale

Spec.	Prod.	Sum Gross CCF[1]	Sum Net CCF[2]	Total Value($)[3]	Est. Tons Removed[4]	Average $/Ton[5]
All	All	135.94	123.41	7708.60	356.8	21.60

[1]Sum Gross CCF = Sum of the Gross CCF from Table 2.
[2]Net CCF = Sum of the Net CCF from Table 2.
[3]Total Value ($) = Sum of the Individual Species Values from Table 2.
[4]Est. Tons Removed = Sum of the Individual Est. Tons Removed from Table 2.
[5]Average $/Tons = Total Value ($)/Est. Tons Removed.

85 - Moisture Content

The average moisture content (MC) of wood and bark for the species and product is calculated using green weight factor and dry weight factor as:

$$MC = \frac{GrnWtFac - DryWtFac}{DryWtFac} X\ 100$$

Where:

MC = average moisture content (%)
$GrnWtFac$ = green weight factor
$DryWtFac$ = dry weight factor

The green weight factor can be obtained using the methods in section 82. The dry weight factor can be obtained using the disk scaling procedure in section 82.4. When the dry weight factor is not able to be obtained, it is recommended to use the dry weight factor (that is, Avg. oven-dry weight of wood and bark (lb/cf)) from Miles & Smith (2009) as shown in exhibit 01. When the green weight factor is also not available, the Avg. green weight of wood and bark (lb/cf) is used as green weight factor.

85 – Exhibit 01

Avg. oven-dry weight Miles & Smith (2009)

Table 1B.—Average oven-dry and green weight of wood and bark when only wood volume is known for tree species in North America. Reference numbers in this table refer to numbered citations found in Literature Cited section of this report.

							Total oven-dry and green weight of wood and bark per cubic foot of wood *			
Common name	Genus	Species	FIA code	Wood reference	Bark reference	Bark % reference (Tab 3)	*Avg. oven-dry weight of wood and bark (lb/cf)*	*Avg. oven-dry weight of wood and bark (kg/m3)*	*Avg. green weight of wood and bark (lb/cf)*	*Avg. green weight of wood and bark (kg/m3)*
Pacific silver fir	Abies	amabilis	11	25	30	30	29	461	49	781
Balsam fir	Abies	balsamea	12	25	12	9	24	378	51	817
White fir	Abies	concolor	15	25	12	a	27	437	54	862
Grand fir	Abies	grandis	17	25	12	a	26	418	52	832
Subalpine fir	Abies	lasiocarpa	19	25	12	21	23	364	33	536
California red fir	Abies	magnifica	20	25	12	a	25	407	52	826
Noble fir	Abies	procera	22	25	12	a	26	423	35	567
Port-Orford-cedar	Chamaecyparis	lawsoniana	41	25	25	a	27	436	47	754
Alaska yellow-cedar	Chamaecyparis	nootkatensis	42	25	29	21	29	466	51	819
Atlantic white-cedar	Chamaecyparis	thyoides	43	25	29	a	22	356	42	669
Alligator juniper	Juniperus	deppeana	63	2	28	a	33	528	45	718
Utah juniper	Juniperus	osteosperma	65	3	b	a	46	730	62	997
Southern redcedar	Juniperus	virginiana	67	2	b	a	29	468	42	670
Eastern redcedar	Juniperus	virginiana	68	25	29	23	30	488	42	670
Tamarack (native)	Larix	laricina	71	25	12	23	33	532	52	836
Western larch	Larix	occidentalis	73	25	12	a	33	526	53	845
Incense-cedar	Calocedrus	decurrens	81	25	30	a	24	392	48	775
Engelmann spruce	Picea	engelmannii	93	25	12	21	24	387	45	727
White spruce	Picea	glauca	94	25	12	a	26	421	41	650
Black spruce	Picea	mariana	95	25	12	a	27	434	42	665
Red spruce	Picea	rubens	97	25	12	a	26	411	39	618
Sitka spruce	Picea	sitchensis	98	25	12	21	25	399	41	653
Knobcone pine	Pinus	attenuata	103	30	b	30	27	435	55	878
Jack pine	Pinus	banksiana	105	25	12	9	29	457	57	911
Common or two-needle pinyon	Pinus	edulis	106	2	b	a	35	553	45	727
Sand pine	Pinus	clausa	107	25	12	26	33	527	46	736
Lodgepole pine	Pinus	contorta	108	25	12	21	26	413	42	680
Shortleaf pine	Pinus	echinata	110	25	12	26	33	526	58	923
Slash pine	Pinus	elliottii	111	25	12	26	38	603	65	1047
Limber pine	Pinus	flexilis	113	2	b	a	27	437	50	796
Spruce pine	Pinus	glabra	115	25	b	a	29	470	50	796
Jeffrey pine	Pinus	jeffreyi	116	30	12	a	29	462	55	876
Sugar pine	Pinus	lambertiana	117	25	25	a	27	429	59	950
Western white pine	Pinus	monticola	119	25	12	21	26	419	42	670
Bishop pine	Pinus	muricata	120	30	b	a	34	549	54	862
Longleaf pine	Pinus	palustris	121	25	12	26	38	603	62	1000
Ponderosa pine	Pinus	ponderosa	122	25	12	21	29	469	52	840
Table Mountain pine	Pinus	pungens	123	2	b	a	34	550	60	962
Monterey pine	Pinus	radiata	124	2	b	a	28	454	55	887
Red pine	Pinus	resinosa	125	25	12	23	28	453	47	755
Pitch pine	Pinus	rigida	126	25	12	a	32	515	55	887

85 – Exhibit 01 -- Continued

Table 1B.—continued

							Total oven-dry and green weight of wood and bark per cubic foot of wood *			
Common name	Genus	Species	FIA code	Wood reference	Bark reference	Bark % reference (Tab 3)	Avg. oven-dry weight of wood and bark (lb/cf)	Avg. oven-dry weight of wood and bark (kg/m3)	Avg. green weight of wood and bark (lb/cf)	Avg. green weight of wood and bark (kg/m3)
Gray or California foothill pine	Pinus	sabiniana	127	30	b	30	30	488	54	862
Pond pine	Pinus	serotina	128	25	b	a	35	554	56	903
Eastern white pine	Pinus	strobus	129	25	b	9	26	415	43	689
Loblolly pine	Pinus	taeda	131	25	12	19	33	525	60	958
Virginia pine	Pinus	virginiana	132	25	b	a	33	522	59	938
Douglas-fir	Pseudotsuga	menziesii	202	25	12	21	33	526	47	753
Redwood	Sequoia	sempervirens	211	25	12	30	27	437	56	890
Giant sequoia	Sequoiadendron	giganteum	212	30	30	a	25	401	63	1017
Baldcypress	Taxodium	distichum	221	25	29	26	32	520	63	1016
Pacific yew	Taxus	brevifolia	231	2	30	30	39	623	58	928
Northern white-cedar	Thuja	occidentalis	241	25	23	9	22	349	43	689
Western redcedar	Thuja	plicata	242	25	12	21	22	349	31	493
Eastern hemlock	Tsuga	canadensis	261	25	12	9	29	458	60	956
Western hemlock	Tsuga	heterophylla	263	25	12	21	31	499	51	816
Mountain hemlock	Tsuga	mertensiana	264	25	12	a	30	484	52	829
Bigleaf maple	Acer	macrophyllum	312	25	13	30	30	488	53	855
Boxelder	Acer	negundo	313	31	b	a	29	463	55	884
Black maple	Acer	nigrum	314	25	b	a	38	604	65	1041
Striped maple	Acer	pensylvanicum	315	1	b	a	30	483	52	834
Red maple	Acer	rubrum	316	25	13	11	34	541	56	893
Silver maple	Acer	saccharinum	317	25	13	a	31	489	52	825
Sugar maple	Acer	saccharum	318	25	13	11	40	644	65	1041
Yellow buckeye	Aesculus	flava	332	1	13	a	25	405	59	943
Ailanthus	Ailanthus	altissima	341	1	b	a	33	527	58	921
Red alder	Alnus	rubra	351	25	13	21	27	437	53	855
Serviceberry spp.	Amelanchier	spp.	356	1	26	a	44	703	65	1046
Pacific madrone	Arbutus	menziesii	361	1	26	a	42	670	69	1105
Yellow birch	Betula	alleghaniensis	371	25	25	21	38	611	65	1043
Sweet birch	Betula	lenta	372	25	25	a	41	661	71	1130
River birch	Betula	nigra	373	1	b	a	34	544	62	992
Paper birch	Betula	papyrifera	375	25	25	c	34	550	59	940
Gray birch	Betula	populifolia	379	1	13	a	32	519	53	850
American hornbeam, musclewood	Carpinus	caroliniana	391	1	26	a	39	627	59	939
Water hickory	Carya	aquatica	401	25	25	a	44	706	80	1275
Bitternut hickory	Carya	cordiformis	402	25	25	a	43	696	74	1179
Pignut hickory	Carya	glabra	403	25	13	a	47	756	78	1243
Pecan	Carya	illinoinensis	404	25	25	a	43	696	72	1147
Shellbark hickory	Carya	laciniosa	405	25	13	a	45	716	74	1179
Nutmeg hickory	Carya	myristiciformis	406	25	29	a	41	656	72	1147
Shagbark hickory	Carya	ovata	407	25	13	a	47	755	74	1179
Mockernut hickory	Carya	alba	409	25	25	a	46	736	75	1195
American chestnut	Castanea	dentata	421	25	25	a	30	475	64	1023

85 – Exhibit 01 – Continued

Table 1B.—continued

Common name	Genus	Species	FIA code	Wood reference	Bark reference	Bark % reference (Tab 3)	Total oven-dry and green weight of wood and bark per cubic foot of wood *			
							Avg. oven-dry weight of wood and bark (lb/cf)	Avg. oven-dry weight of wood and bark (kg/m3)	Avg. green weight of wood and bark (lb/cf)	Avg. green weight of wood and bark (kg/m3)
Giant chinkapin, golden chinkapin	Chrysolepis	chrysophylla	431	1	26	30	29	470	67	1073
Northern catalpa	Catalpa	speciosa	452	1	26	a	28	455	50	799
Hackberry	Celtis	occidentalis	462	25	29	23	35	563	59	940
Flowering dogwood	Cornus	florida	491	1	b	a	45	727	63	1015
Pacific dogwood	Cornus	nuttallii	492	18	b	a	42	667	63	1015
Common persimmon	Diospyros	virginiana	521	26	26	a	45	715	72	1151
American beech	Fagus	grandifolia	531	25	13	11	37	600	59	941
White ash	Fraxinus	americana	541	25	25	a	39	630	59	952
Oregon ash	Fraxinus	latifolia	542	25	b	a	36	580	59	952
Black ash	Fraxinus	nigra	543	25	13	a	32	519	60	964
Green ash	Fraxinus	pennsylvanica	544	25	29	26	38	607	60	964
Pumpkin ash	Fraxinus	profunda	545	1	b	a	34	552	58	937
Blue ash	Fraxinus	quadrangulata	546	25	b	a	37	592	57	919
Honeylocust	Gleditsia	triacanthos	552	25	26	a	42	675	69	1103
Kentucky coffeetree	Gymnocladus	dioicus	571	1	b	a	38	605	58	921
Silverbell spp.	Halesia	spp.	580	1	26	a	31	495	53	847
American holly	Ilex	opaca	591	1	26	a	36	575	66	1055
Butternut	Juglans	cinerea	601	25	13	a	26	420	53	850
Black walnut	Juglans	nigra	602	25	13	a	35	559	63	1007
Sweetgum	Liquidambar	styraciflua	611	25	13	5	33	523	58	921
Yellow-poplar	Liriodendron	tulipifera	621	25	25	5	29	468	58	932
Tanoak	Lithocarpus	densiflorus	631	25	26	30	44	697	77	1230
Osage-orange	Maclura	pomifera	641	1	26	a	53	850	71	1137
Cucumbertree	Magnolia	acuminata	651	25	13	a	32	506	57	910
Southern magnolia	Magnolia	grandiflora	652	25	13	a	33	526	67	1070
Sweetbay	Magnolia	virginiana	653	1	b	a	30	486	57	919
Mountain or Fraser magnolia	Magnolia	fraseri	655	1	b	a	29	466	57	910
Apple spp.	Malus	spp.	660	26	25	a	43	685	76	1213
Water tupelo	Nyssa	aquatica	691	25	29	a	34	541	65	1045
Blackgum	Nyssa	sylvatica	693	25	25	26	33	521	64	1030
Eastern hophornbeam	Ostrya	virginiana	701	1	26	a	44	705	69	1103
Sourwood	Oxydendrum	arboreum	711	18	26	a	37	590	62	993
American sycamore	Platanus	occidentalis	731	25	13	23	32	508	58	921
Balsam poplar	Populus	balsamifera	741	25	13	a	26	420	53	845
Eastern cottonwood	Populus	deltoides	742	25	29	30	28	453	58	931
Bigtooth aspen	Populus	grandidentata	743	25	13	a	28	445	53	850
Quaking aspen	Populus	tremuloides	746	25	29	21	26	422	59	946
Black cottonwood	Populus	balsamifera	747	25	13	21	23	375	54	868
Fremont cottonwood	Populus	fremontii	748	30	b	a	31	500	51	813
Mesquite spp.	Prosopis	spp.	755	31	b	a	55	877	68	1082
Black cherry	Prunus	serotina	762	25	29	11	33	528	52	831
White oak	Quercus	alba	802	25	13	5	43	689	74	1178

85 – Exhibit 01 -- Continued

Table 1B.—continued

Common name	Genus	Species	FIA code	Wood reference	Bark reference	Bark % reference (Tab 3)	Total oven-dry and green weight of wood and bark per cubic foot of wood *			
							Avg. oven-dry weight of wood and bark (lb/cf)	*Avg. oven-dry weight of wood and bark (kg/m3)*	*Avg. green weight of wood and bark (lb/cf)*	*Avg. green weight of wood and bark (kg/m3)*
Swamp white oak	Quercus	bicolor	804	25	13	a	45	728	73	1176
Canyon live oak	Quercus	chrysolepis	805	30	13	a	50	802	88	1412
Scarlet oak	Quercus	coccinea	806	25	13	a	47	756	79	1258
Southern red oak	Quercus	falcata	812	25	13	5	42	669	78	1247
Cherrybark oak	Quercus	pagoda	813	25	13	a	47	748	80	1289
Gambel oak	Quercus	gambelii	814	3	13	a	47	748	77	1238
Oregon white oak	Quercus	garryana	815	1	13	a	46	740	73	1176
California black oak	Quercus	kelloggii	818	18	13	a	38	609	76	1212
Laurel oak	Quercus	laurifolia	820	25	13	a	40	640	75	1202
California white oak	Quercus	lobata	821	30	13	a	40	638	73	1176
Overcup oak	Quercus	lyrata	822	25	13	a	43	682	76	1221
Bur oak	Quercus	macrocarpa	823	25	13	a	42	666	73	1173
Swamp chestnut oak	Quercus	michauxii	825	25	13	a	45	717	77	1230
Water oak	Quercus	nigra	827	25	13	a	41	659	75	1197
Pin oak	Quercus	palustris	830	25	13	a	44	712	80	1275
Willow oak	Quercus	phellos	831	25	13	a	41	654	75	1205
Chestnut oak	Quercus	prinus	832	25	13	5	43	694	75	1208
Northern red oak	Quercus	rubra	833	25	13	9	43	696	80	1285
Post oak	Quercus	stellata	835	25	13	a	44	712	77	1237
Black oak	Quercus	velutina	837	25	13	11	42	671	77	1236
Live oak	Quercus	virginiana	838	25	13	a	55	881	86	1371
Black locust	Robinia	pseudoacacia	901	25	26	a	44	703	63	1011
Black willow	Salix	nigra	922	25	13	a	27	440	61	976
Sassafras	Sassafras	albidum	931	25	26	a	31	495	53	847
American basswood	Tilia	americana	951	25	25	c	23	370	47	753
Winged elm	Ulmus	alata	971	1	b	a	41	663	60	959
American elm	Ulmus	americana	972	25	25	a	33	521	63	1002
Cedar elm	Ulmus	crassifolia	973	1	25	a	41	653	68	1087
Slippery elm	Ulmus	rubra	975	25	b	a	32	520	60	959
Rock elm	Ulmus	thomasii	977	25	25	a	40	640	61	970
California-laurel	Umbellularia	californica	981	1	30	a	37	592	60	967

* *Moisture content is extremely variable and the values shown are averages or estimates based on the literature cited.*
a No reference source available, estimated based on similar species.
b Based on green volume specific gravity and bark moisture content of similar species.
c Adapted from McCormack (1955) using supplemental data from Forbes (1956) and Koch (1971)