5.0 Assessing Primary Forest Products

Some units of measurement & definitions

Log - section of a tree bole at least 8 ft in length

Stick, bolt - section of a tree bole shorter than 8 ft

Cubic ft - a quantity of substance equivalent to that which would be found in a cube with dimensions 1 ft x 1 ft x 1ft

Board ft - a quantity of wood equivalent to that which would be found in a board with dimensions 1 in. t x 1 ft w x 1 ft l

Contents of a board = $\frac{t(in.) \times w(in.) \times l(ft)}{12}$

Cubic meter - a quantity of substance equivalent to that which would be found in a cube with dimensions 1 m x 1 m x 1 m

Cord - stacked pile of round wood measuring 4 ft x 4 ft x 8 ft (l x h x w)

- short cord refers to stacked wood with 32 sq.ft of face, but shorter stick length than 4 ft
- pulpwood, firewood typically sold using this unit of measure
- though dimensions indicate 128 cu.ft contents, must consider method of piling, species, diameter & length of sticks, straightness, freedom from knots, stc.
  - 10 – 30% of total stick volume is bark for coniferous species
  - 90 cu.ft per cd is more typical for PNW
  - 79 cu.ft per cd is used in the Lake states
  - 72 cu.ft per cd is used for southern pines

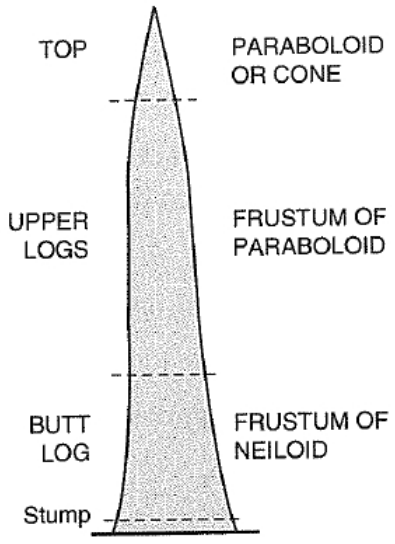

Exhibit. Geometric shapes assumed by different portions of tree boles.

Exhibit. Common formulae used to describe sections (frusta) of common geometric solids

Geometric Solid(s)	:	Formula for Volume, V	(Formula name)
Paraboloid	:	$V = h\,(A_m)$	(Huber's)
	:	$V = h\frac{A_b + A_u}{2}$	(Smalian's)
Conic frustum	:	$V = h\,\frac{1}{3}\left(A_b + \sqrt{A_b \cdot A_u} + A_u\right)$	
Neiloid frustum	:	$V = h\,\frac{1}{4}\left(A_b + \sqrt[3]{A_b^2 \cdot A_u} + \sqrt[3]{A_b \cdot A_u^2} + A_u\right)$	
Cone, Parab., Neil. frustum	:	$V = h\,\frac{A_b + 4(A_m) + A_u}{6}$	(Newton's formula*)

* Newton's formula is closely approximate for all given geometric solids

where,

A_b = cross-sectional area at base, or large end of log or section
A_m = cross-sectional area at log or stem section midpoint
A_u = cross-sectional area at upper, or small end of log or section
h = log or section length

NOTE: trees in cross-section are rarely circular, but always presumed so.

The Assessment Process – Log Scaling

- Scaling - the process of measuring volumes of individual logs (implicitly understood that the objective is sound, solid wood, excluding bark). The process used is measuring diameter and length to obtain gross volume based on log rule
- Log rule - standardized set of steps to follow to estimate log volume from diameter and length measurements – two types: formula, diagram
- Trim allowance - short length of log required to allow acceptable length criterion to be met after "evening up" the ends
- Total volume - (a.k.a. "gross" volume) volume of wood including defects, such as rot, voids, etc.
- Sound volume - (a.k.a. "net") volume of sound wood (excludes, rot, voids, etc.)

Log scaling originally constituted an attempt to estimate, before processing, the amount of product in logs and trees. Therefore differentiation between the measurement of volumetric contents of *sawn* lumber or veneer, that is *mill tally*, and the estimation of volumetric contents of logs, that is *log scale*, must be made. Typically, this variation is quantified with the formula:

$$O_v(in\ percent) = \left[\left(\frac{Mill\ Tally}{Log\ Scale}\right) - 1\right] 100$$

When this quantity is positive, an *overrun* has been produced, when negative, an *underrun* has been produced.

Purposes:

- to measure amount of product being sold
- to measure amount of work performed
- to check accuracy of timber cruise (inventory) estimates

Scaler qualifications:

- ability to balance the combination of rule application and judgment tempered by experience
- ability to do this consistently
- integrity: scaler is final appraiser of quality and quantity of sound wood in the sale

Types of Scale:

- water
- truck
- roll-out
- weight

5.1 Cubic Foot Log Scaling

- always use formula log rules (formulas include Huber's, Smalian's, Newton's, etc.)
- cubic volumes are derived simply by multiplying average cross-section area by length of log in feet
- if log is cylinder: no problem
- trouble occurs when we have taper – how do we define average cross-sectional area?

Interagency Cubic Foot System

Devised to satisfy need to have a standardized method for scaling; officially adopted by the USFS and the BLM in 1991 and approved by NLRAG

Procedure

Scaling Diameters. At each end, take a pair of inside bark diameter (dib) readings at right angles to each other. Round each diameter to nearest inch, average, and drop any remaining fraction – record the result.

Scaling Length. Measure the length of the log to nearest 0.1 ft then round to the nearest foot using trim specifications appropriate for the given log length. Trim allowance varies from –0.4 to 1 ft for logs up to 22 feet in length. Trim allowance varies from 0.1 to 1.0 ft for log lengths of 22.1 ft and greater (Table 2-2).

Scaling Segments. If scaling length is 20 ft or less, apply Smalian's formula to the recorded dimensions to compute volume.

If longer than 20 ft, subdivide the log into (virtual) whole-foot segments that are as equal in length as possible. In cases where segments are unequal in length, the long log is the bottom log (large end of log). Odd segment scaling lengths are permissible only when original long log recorded length is odd.

Estimate taper as the difference in recorded diameter dimensions. Allocate taper in whole inches as evenly as possible to the segments, placing the greatest taper in the top segment. Apply Smalian's formula to each segment, totaling up all the segments to arrive at log volume.

Using segments is intended to reduce the slight bias in use of Smalian's formula.

Recorded volume. Record volume resulting from application of Smalian's formula to the nearest 0.1 cu.ft.

Table 2-2. *Partial list of recorded log lengths and scaling segments for the Interagency Cubic Foot log rule.*

		Scaling segments		
Measurement (ft)	Recorded as	Bottom	Middle	Top
8.0-8.5	8	8	—	—
8.6-9.5	9	9	—	—
⋮				
19.6-20.5	20	20	—	—
20.6-22.0	21	11	—	10
22.1-23.0	22	12	—	10
23.1-24.0	23	12	—	11
⋮				
40.1-41.0	40	20	—	20
41.1-42.0	41	14	14	13
42.1-43.0	42	14	14	14
43.1-44.0	43	15	14	14
etc.				

Logs 61-80 feet in length are divided into four segments.

Source: USFS (1991).

Table 2-3. *Interagency Cubic Foot log scale applied to 15 sample logs.*[a]

Diameter[b]				Scaling segments			Total vol.
Small (in)	Large (in)	Length (ft)	Recorded size	Top	Middle	Bottom	(ft^3)
13.8	20.4	27.0	14 x 20 x 26	14 x 17 x 12		17 x 20 x 14	42.2
17.0	27.5	41.0	17 x 28 x 40	17 x 23 x 20		23 x 28 x 20	116.2
12.3	19.4	44.9	12 x 19 x 44	12 x 15 x 14	15 x 17 x 14	17 x 19 x 16	61.0
14.5	22.1	44.3	14 x 22 x 44	14 x 17 x 14	17 x 20 x 14	20 x 22 x 16	83.4
7.2	13.0	20.9	7 x 13 x 21	7 x 10 x 10		10 x 13 x 11	12.2
6.0	10.6	28.8	6 x 11 x 28	6 x 9 x 14		9 x 11 x 14	12.2
17.7	27.3	27.1	18 x 27 x 27	18 x 23 x 13		23 x 27 x 14	78.2
6.3	12.8	23.5	6 x 13 x 23	6 x 10 x 11		10 x 13 x 12	12.9
10.4	16.1	26.9	10 x 16 x 26	10 x 13 x 12		13 x 16 x 14	25.0
17.4	23.2	35.3	17 x 23 x 35	17 x 20 x 17		20 x 23 x 18	77.5
5.5	9.0	39.0	6 x 9 x 38	6 x 8 x 18		8 x 9 x 20	12.8
7.0	15.0	40.9	7 x 15 x 40	7 x 11 x 20		11 x 15 x 20	28.2
15.0	17.2	34.7	15 x 17 x 34	15 x 16 x 16		16 x 17 x 18	47.8
12.6	18.3	34.9	13 x 18 x 34	13 x 16 x 16		16 x 18 x 18	47.0
6.4	8.3	14.9	6 x 8 x 15	6 x 8 x 15			4.1
						Total	660.7

[a]The sample logs, while taken from intensively managed young plantations, are intended only to illustrate methodology. They should not be construed as representing any particular log sort or the resource in general. The results obtained and differences between the log rules discussed in this chapter may change

5.2 Board Foot Log Scaling

- may use formula or diagram log rules
- over the years, literally hundreds of bd.ft log rules have been devised, most of them were not reliable and have long been forgotten

General features of board-foot log rules

- consistency: volumes should be directly correlated with log sizes over the entire range of dimensions encountered
- logs are considered to be cylinders
- assume that all logs will be processed into boards of certain thickness with a saw of specified thickness (determines kerf)
- assume a minimum board width, and maximum scaling length
- assume that there is a fixed procedure for sawing the log
- assume that every sawmill will get the same amount of lumber out of given log dimensions

Scribner Log Rule

- developed by J.M Scribner in 1846
- diagram log rule derived from scale drawings of log-ends (circles) in which 1-in. thick boards were inscribed
- saw kerf is assumed to be ¼ in.
- exact minimum board width is unknown, but appears to be 4 in.
- no allowance for taper – underestimates contents of long logs
- maximum log length is 32 ft
- intermediate in accuracy

- Scribner Decimal C is a ubiquitous variant, developed as an aid to scalers: Scribner scale is computed to nearest 10 bd.ft then trailing zero is dropped

Westside Scribner Scaling System (west of Cascades in WA & OR)

Approved by NLRAG for its consistency, sometimes called “long log Scribner”

Procedure

Scaling Diameters. Measure inside bark diameter (dib) at small end of log only. Take two measurements through the true center of the end area at right angles to each other – short axis measured first – fractions of inches dropped. Average the results, drop remaining fraction. Record this value → defines the scaling cylinder.

Scaling Length. Measure length from short side of log. Maximum log length is 40 feet. Trim maximum is 12 in., minimum is zero. Over 40 feet, an additional 2 in. of trim per 10 ft. is allowed.

Scaling Segments. Logs 40 ft or less in gross length are scaled as a single log. Logs 41 ft to 80 ft are scaled as two logs of as equal length as possible (longer log is always the top log). Logs 81 to 120 ft are scaled as three logs. Taper is assumed to be 1 inch per 10 ft.

Recorded Volume. Consult Scribner volume table using scaled diameter and length. Round to nearest 10 bd.ft, record result in Scribner Decimal C.

Table 1. Factors for Computing Scribner Log Volumes.

FACTORS FOR COMPUTING LOG VOLUMES,
SCRIBNER TABLE AS REVISED 7/1/72
FOR LOGS 1′ THROUGH 40′ IN LENGTH

	Dia.	Factor	Dia.	Factor	Dia.	Factor
1′ thru 15′	1″	0.000	39″	70.000	81″	317.360
	2	0.143	40	75.240	82	325.790
	3	0.390	41	79.480	83	334.217
	4	0.676	42	83.910	84	343.290
	5	1.070	43	87.190	85	350.785
	6	1.160*	44	92.501	86	359.120
	7	1.400*	45	94.990	87	368.380
	8	1.501*	46	99.075	88	376.610
	9	2.084*	47	103.501	89	385.135
	10	3.126*	48	107.970	90	393.380
	11	3.749*	49	112.292	91	402.499
16′ thru 31′	6	1.249*	50	116.990	92	410.834
	7	1.608*	51	121.650	93	419.166
	8	1.854*	52	126.525	94	428.380
	9	2.410*	53	131.510	95	437.499
	10	3.542*	54	136.510	96	446.565
	11	4.167*	55	141.610	97	455.010
32′ thru 40′	6	1.570*	56	146.912	98	464.150
	7	1.800*	57	152.210	99	473.430
	8	2.200*	58	157.710	100	482.490
	9	2.900*	59	163.288	101	491.700
	10	3.815*	60	168.990	102	501.700
	11	4.499*	61	174.850	103	511.700
	12	4.900	62	180.749	104	521.700
	13	6.043	63	186.623	105	531.700
	14	7.140	64	193.170	106	541.700
	15	8.880	65	199.120	107	552.499
	16	10.000	66	205.685	108	562.501
	17	11.528	67	211.810	109	573.350
	18	13.290	68	218.501	110	583.350
	19	14.990	69	225.685	111	594.150
	20	17.499	70	232.499	112	604.170
	21	18.990	71	239.317	113	615.010
	22	20.880	72	246.615	114	625.890
	23	23.510	73	254.040	115	636.660
	24	25.218	74	261.525	116	648.380
	25	28.677	75	269.040	117	660.000
	26	31.249	76	276.630	118	671.700
	27	34.220	77	284.260	119	683.330
	28	36.376	78	292.501	120	695.011
	29	38.040	79	300.655		
	30	41.060	80	308.970		
	31	44.376				
	32	45.975	* Special Note:			
	33	48.990				
	34	50.000	Logs having diameters 6″ through 11″ have a separate diameter factor for lengths 1′ through 15′, 16′ through 31′, and 32′ through 40′.			
	35	54.688				
	36	57.660				
	37	64.319				
	38	66.731				

Eastside Scribner Scaling System (western U.S., except west of Cascades in WA, OR)

Approved by NLRAG, sometimes called “short log” Scribner

Procedure

Log measurements and segmenting procedures are the same as for the Interagency Cubic Foot System, except maximum log length is 16 feet.

Find Scribner volume for each segment based on small end diameter then sum segment volumes to obtain whole log volume.

5.3 Log Defects and Grading

Log Defects

- logs with no defects have total (gross) scale equal to sound (net) scale
- defects refer only to imperfections that cause loss in wood volume when sawn:
    - rot, worm holes, ring shake, splits, checks, and crook;
    - NOT for sound knots, coarse grain, sap stain, or small pitch pockets – these generally cause degrades
    - operating defects include breakage, splits, and brooming
- extent of interior log defects can only be learned by working with experienced scalers and watching defective logs get sawn into boards on the mill carriage
- no deductions are made for defects outside the scaling cylinder or for those penetrating 1-in. or less into it (bd.ft scale only)
- Common approaches to making defect deductions in scaling:
    - Reduce log diameter – use for exterior defects such as excessive roughness, checks, sap rot, cat face, pitch ring, heart check, split
    - Reduce log length – use for butt rot, heart rot, crook, end brooming, sweep, conk, pitch spangle, breaks, stump shake
    - Diagramming defects for mathematical computations – for interior and partially hidden defects
        - Defect enclosed in an imaginary solid and defective contents are subtracted from gross scale, assuming 1” boards
            - bd.ft loss $= \frac{w \times t \times l}{15}$,
            - w = width of defect enclosure (in.)
            - t = thickness of defect enclosure (in.)
            - l = length of defect enclosure (ft)
        - Formula is reminiscent of that for bd ft volume except that the denominator is 15 rather than 12 – accounts for the fact that 20% has already been deducted for kerf
            - cubic ft loss $= \frac{w \times t \times l}{144}$, all variables as before.
        - When applying the diagram method, 1” is usually added to the width and thickness of the defect to “square” it up

- Merchantability of logs varies by locality, kind of log, and changing economic conditions, but usually, if 50% or more of the log is sound, it's merchantable, otherwise it is culled.
- Logical, simple system for determining net scale consistent between bd ft and cubic ft scaling systems proposed by Grosenbaugh
    - Amount of lumber lost in defect is estimated simply by multiplying gross scale from ANY log rule by the proportion of the log affected.
    - Five equations handle all common defects (P_d denotes proportion of log that is defective)
        - 1) Defect affects entire section of log
            - $P_d = \frac{l}{L}$
            - l denotes length of defect (ft); L denotes total log length (ft)
        - 2) Defect affects a wedge-shaped section of log
            - $P_d = \frac{l}{L}\left(\frac{\alpha}{360}\right)$
            - α denotes central angle of wedge-shape in degrees
        - 3) Log has a long sweep
            - $P_d = \frac{S_w - 2}{D}$
            - S_w denotes departure of central log axis from a straight axis connecting centers of two end areas (inches); D denotes top scaling diameter of log
        - 4) Log has a significant crook
            - $P_d = \left(\frac{l_d}{L}\right)\left(\frac{C}{D}\right)$
            - l_d denotes length of deflecting section (ft); C denotes maximum deflection (in.) of axis of crook from straight axis of log
        - 5) Log has a defect that can be enclosed in a circle or ellipse
            - $P_d = \frac{(d_a + 1)(d_b + 1)}{(D-1)^2}\left(\frac{l}{L}\right)$
            - d_a denotes major axis diameter of defect, d_b denotes minor axis diameter of defect

Log Grading

- Two factors go into determining value of the log – quantity and quality
- Grading defects are those defects that reduce strength or appearance or would otherwise limit the utility of a sawn product
- Grading remains an elusive endeavor – there is little standardization, esp. for conifers
    - A given log will produce lumber of several grades
    - Objective is to maximize the value of the log, the proportion of grades will vary with manufacturing technology & market conditions

DOUGLAS-FIR SAWMILL LOGS.

No. 1 Sawmill Douglas-fir. Logs shall be suitable for manufacture of B and Better lumber to an amount of not less than 50% of the NET scale. Such logs shall meet at least the following minimum exterior characteristics:

Gross diameter - 30 inches.
Gross length - 16 feet
Surface - 90% clear.
Annual ring count - 8 per inch.
Slope of grain - not to exceed 3" per foot.

No. 2 Sawmill Douglas-fir. Logs shall be suitable for the manufacture of (1) Construction and Better grades of lumber to an amount of not less than 50% of the NET scale. Such logs shall meet at least the following minimum exterior characteristics:

Gross diameter - 12 inches.
Gross length - 12 feet
Minimum volume - 60 board feet NET scale.
Surface - sound, tight knots, not to exceed 2 1/2" in diameter. Any larger knots, not clusters, and burls shall be so distributed as to permit the required recovery.
Slope of grain - not to exceed:
2" per foot on logs 12" thru 20".
3" per foot on logs 21" thru 35".
4" per foot on logs 36" thru 50".
5" per foot on logs 51" and over.

No. 3 Sawmill Douglas-fir. Logs shall be suitable for the manufacture of Standard and Better grades of lumber to an amount of not less than 33 1/3% of the GROSS scale. Such logs shall meet at least the following minimum exterior characteristics:

Gross diameter - 6 inches.
Gross length - 12 feet
Minimum volume - 50 board feet NET scale.
Surface - sound, tight knots, not to exceed 3" in diameter. Any larger knots, knot clusters, and burls shall be so distributed as to permit the required recovery.
Slope of grain - may include logs having "excessive slope of grain" with proper deduction.

No. 4 Sawmill Douglas-fir. Logs shall be suitable for the manufacture of Standard and Better grades of lumber to an amount of not less than 33 1/3% of the GROSS scale. Such logs shall meet

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Summary Points

1. Terms to remember: log, stick / bolt, board foot, cubic foot, cord, frustum
2. Log rules come in two flavors: formula or diagram
3. ALL cubic foot rules are formula rules
4. Board-foot rules can be either; Scribner is a diagram rule
5. Smalian's or Huber's formulas are commonly the basis for cu.ft. rules