Historic, archived document

Do not assume content reflects current
scientific knowledge, policies, or practices.

**PACIFIC
NORTH
WEST**
FOREST AND RANGE
EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-226

PNW FOREST AND RANGE
EXPERIMENT STATION

May 1974

DEC 6 1974

STATION LIBRARY COPY

EFFECT ON DIAMETER ESTIMATES OF ROUNDING RULES IN SCALING

by

David Bruce, *Chief Mensurationist*

and

Donald J. DeMars, *Associate Mensurationist*

ABSTRACT

Treatment of diameter measurements in Pacific Northwest scaling practice results in lower recorded diameters than those obtained by measuring to the nearest one-tenth inch. This would bias cubic volume estimates unless appropriately adjusted.

Keywords: Log scaling, measurement systems.

INTRODUCTION

Recently, two Scaling Bureaus have agreed to scale logs with two end-diameter measurements on special request. These measurements should make possible accurate estimates of the cubic-foot volume of the scaled logs. However, two current board-foot scaling practices will bias these estimates.

On the west side of the Cascade Range the scaling practice is to drop fractional inches and use the next lower full inch of diameter. Out-of-round logs have both the long diameter and the short diameter measured this way. The recorded diameter is the average of two measurements taken to the next lower inch. If this average is not a whole number, the fraction is dropped before recording.

On the east side, diameters are scaled to the nearest inch. However, again, two such measurements--long and short diameters--are averaged before recording. If there is a fraction, it is always a half-inch and it is dropped before recording.

These scaling procedures suggest many questions:

1. How much bias is caused by scaling to the next lower inch?
2. Is any bias caused by scaling to the nearest inch?
3. How much bias is caused by dropping half-inches before recording the average of the long and short diameters?
4. How many logs must be measured before variation around expected biases is reduced to about 0.05 inch?
5. How much effect do these biases have on volume estimates? All these questions, except the third, can be

answered by use of mathematical theory.

Since mathematical theory is more convincing to some when it has a simple demonstration in observed results, we looked for suitable field records. We found scaling records of nearly 3,000 logs cut from over 700 Douglas-fir trees in mill recovery studies performed by the Station's Timber Quality Project. This includes both old-growth and young-growth trees; but more importantly, it includes logs whose scaling diameters were measured to the nearest one-tenth inch.

These records were used to compare west-side and east-side scaling practices with the possibly more accurate practice of measuring diameters to the nearest one-tenth inch and retaining the fraction when averaging long and short diameters. It is recognized that no attempt should be made in practical work to measure this closely large logs with irregularly shaped ends. However, such records can be used to detect the biases in which we were interested.

Consideration of the theoretical aspects of the problem suggested we should include in our comparisons modifications of the west-side and east-side rules. These were to record the half-inch when rounded long and short diameters were averaged. The modified east-side rule, measuring to the nearest inch and retaining the half-inch in the average when it occurred, should have no bias when compared with measurements to the nearest one-tenth inch on a large enough number of logs. The alternative possibility of always rounding the average diameter to the nearest even number of inches was not tested because it would increase variability. (There would be about three times as many logs assigned even-inch diameters as odd-inch.)

The reader not interested in technical stuff and theoretical outcomes can skip to the results section.

TECHNICAL STUFF

Both west-side and east-side scale sticks have marks dividing them into 1-inch intervals. On west-side sticks, these intervals are marked at points a full number of inches from the zero end of the stick. On east-side sticks they are offset to the half-inch points. A west-side scale stick assigns a 12-inch diameter to logs whose diameter inside bark falls between the marks at 12.0 and 13.0 inches. An east-side stick does the same for diameters between 11.5 and 12.5 inches. It is easy to see that the difference in graduations on the west-side and east-side rules makes the exact average of a large number of west-side measurements a half-inch smaller than the average of the east-side measurements on the same logs.

When the logs were measured to the nearest one-tenth inch, a scale graduated in inches and tenths was used. A measurement was assigned to the log by placing the 0 division on one side and reading the rule to the tenth inch nearest the other side of the log. Thus any diameter that fell within 0.05 inch of the tenth-inch mark was assigned the tenth-inch value.

Converting these measurements to west-side and east-side measurements is complicated whenever a tenth-inch diameter coincides with a graduation mark on the scale stick being tested. For west-side scaling this occurs at full inches and for east-side scaling, at half-inches. At these points, placement of the nearest tenth-inch measurements into the proper scaling diameter is impossible since

it is unknown if the actual diameter was above or below the tenth-inch mark.

To circumvent this problem, a constant of 0.025 inch was added and subtracted from each tenth-inch diameter measurement recorded for a log. Since each log had two such diameter measurements, four addition-subtraction combinations had to be calculated. Scaling diameters were assigned to each combination and then each rule was tested as now used and as modified to retain the half-inch when averaging the long and short diameters.

THEORETICAL OUTCOMES

As already stated, a half-inch difference was expected between the average of west-side and east-side measurements. Also, it was hypothesized that there would be somewhat less than a quarter-inch difference between each modified rule and its unmodified form for small logs. This was based on the notion that small logs are less out-of-round than large logs and that therefore fewer than half of the average diameters would involve one odd number and one even number. With large logs, a wider range of out-of-roundness would give an expected ratio of one-half the averages being based on one odd and one even diameter, and there should be a quarter-inch bias.

A small amount of arithmetic is needed to calculate theoretically how many logs must be measured to reduce variation to any desired level between mean diameters of logs based on one-tenth-inch measurements and on measurement by 1-inch classes. Take a 1-inch class and divide it into 10 parts. Calculate the deviations of the centers of these 10 classes from the middle of the inch class. The root mean square of these

deviations (0.287 inch) can be taken as an estimate of the standard deviation of a large number of such measurements.

Thus, if 100 logs were put into a single inch class by 1 measurement per log to the nearest inch, the mean of the 100 measurements to the nearest one-tenth inch would have a standard error of 0.0287 inch. Thus, 1 mean value out of 20 such means can be expected to deviate more than 0.0574 inch from the midclass value. The example we deal with is slightly more complicated because our basic record is the average of two diameter measurements.

The theoretical effect on volume estimation of a negative bias in diameter records is easy to work out. Let $V = aD^2L$ for volume of a log based on its average diameter and length. A biased diameter record gives a biased volume estimate $V_B = a(D-B)^2L$. It follows that:

$$\begin{aligned} V_B/V &= (a[D-B]^2L)/(aD^2L) \\ &= (D-B)^2/D^2 \\ &= (D^2 - 2DB + B^2)/D^2 \\ &= 1 - 2B/D + B^2/D^2 \end{aligned}$$

where B^2/D^2 is negligible and the loss in volume expressed as a ratio is about $2B/D$. Thus, a half-inch bias in a 10-inch log biases the volume estimate downward by about 10 percent.

RESULTS

As expected, scaling to the next lower inch (west side) caused the recorded diameters to be about one-half inch lower than scaling to the nearest inch (east side) (table 1, figs. 1 and 2). There was no apparent bias in the modified east-side rule. (The modification was to record any half-inch calculated when averaging the long and short diameters.)

The bias caused by dropping fractional inches when averaging long and short diameters appears to be about 0.20 inch for logs under 10 inches and 0.25 inch for logs over 10 inches.

It takes a large number of logs in each diameter class to reduce variations between mean values estimated from measurements made to different limits of accuracy. However, none of the observed deviations appear to be greater than two standard deviations calculated as suggested in the theoretical section.

Finally the volume biases shown in figure 3 are just about what was expected. These volume biases clearly indicate that some adjustment must be made before calculating cubic volumes from diameters recorded by board-foot scaling practices. Either the east-side practice modified by recording half-inches when averaging should be used or an appropriate amount added to the recorded diameter. In west-side practice this appears to be 0.70 inch for logs under 10 inches and 0.75 inch for logs over 10 inches. In east-side practice, the amounts added would be 0.20 inch for small logs and 0.25 inch for large.

Table 1.--*Biases of average diameters based on four scaling practices expressed as differences from diameters measured to the nearest one-tenth inch and averaged*

Diameter class (inches)	Approximate number of logs	Average diameter measured to one-tenth inch	Biases			
			East-side modified	East side	West-side modified	West side
----- Inches -----						
5.01-10.00	359	8.09	0	-0.21	-0.51	-0.69
10.01-15.00	596	12.56	0	-.26	-.49	-.74
15.01-20.00	557	17.44	+.01	-.26	-.49	-.76
20.01-25.00	469	22.39	+.01	-.27	-.49	-.74
25.01-30.00	372	27.38	-.01	-.27	-.48	-.74
30.01-35.00	270	32.39	0	-.26	-.50	-.75
35.01-40.00	186	37.38	+.01	-.26	-.51	-.77
40.01-45.00	94	42.23	+.02	-.23	-.49	-.74
45.01-64.50	74	49.81	+.01	-.25	-.47	-.73
Sums and means	2,976	21.542	+.001	-.259	-.495	-.744

Figure 1.--Average diameter bias when using east-side modified, east-side, west-side modified, and west-side scaling rules. Based on 1-inch diameter classes starting at 5.01 inches.

Figure 2.--Average diameter bias when using east-side modified, east-side, west-side modified, and west-side scaling rules. Based on 5-inch diameter classes starting at 5.01 inches.

Figure 3.--Ratios of estimated volumes using four scaling rules to estimated volumes using 1/10-inch diameter measurements. Based on 5-inch diameter classes starting at 5.01 inches.