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ABSTRACT

A survey of logging residue was conducted in West Virginia to determine the status of this portion of the State's timber resource. Line intersect methodology was used on 101 sites to determine the volume and weight of residue left after timber harvesting. The mean diameter of residue pieces was 7.0 inches. The average volume of logging residue was 504.4 ft^3/acre, whereas the average weight was 8.41 tons/acre. Both northern red (143.7 ft^3/acre) and white oak (121.1 ft^3/acre) had the greatest volume estimates statewide and were followed by mixed hardwoods (116.1 ft^3/acre) and yellow-poplar (69.8 ft^3/acre). Of the six West Virginia Division of Forestry Districts, District 4 had the greatest overall volume and weight estimates of logging residue following cutting. Among species groups, the greatest volume estimates of red oak, mixed hardwood, yellow-poplar, and soft-hardwood also occurred in District 4. The average volume in any one piece of residue was 12.9 ft^3 statewide, and the majority of logging residue met pulpwood specifications. The greatest volume of sawlog size residue was found in Districts 3 and 5. If logging residue were utilized, approximately 1.5 million tons of residue would be available each year for production, assuming an annual harvest of 180,000 acres. The forest industry in West Virginia is under rapid development, and these results give an indication as to the location and availability of logging residue statewide.

INTRODUCTION

Over the last several years, West Virginia has been extremely successful in attracting new forest products industries. A brief review of these successes would reveal a new flooring mill, a hardwood plywood mill, two oriented strandboard plants, an engineered wood product manufacturer, several new sawmills, and dry kiln facilities. The abundance, maturity, and health of West Virginia's forests have been a significant factor in attracting this new economic development, especially the number of startups focusing on the soft hardwood resource, particularly yellow-poplar (*Liriodendron tulipifera*).

The rapid development of the forest industry in the state has been responsible for the creation of numerous jobs. Effects of this development include impacts on the volume and availability of the timber resource, and the ability of existing log production capability to sustain the demand for roundwood products. This has created a sense of urgency in assessing the current situation before continuing State efforts to attract additional primary forest products companies.

A four-part effort was undertaken in 1995 to investigate the current status of West Virginia's timber resources: a drain survey consisting of a census of primary manufacturers in West Virginia and surrounding states to determine the roundwood harvest for 1994; a mid-cycle reinventory of the standing timber resource in West Virginia; a capacity survey of the West Virginia logging industry to determine its ability to meet increased demands for roundwood; and finally, a determination of the volume of roundwood currently being left in the woods as logging residue. The purpose of this bulletin is to detail the findings of the 1995 logging residue survey so that the potential utilization possibilities of this resource could be assessed.

METHODS

Background: Line intersect sampling of forest residue was first developed by Warren and Olsen (1964) to assess logging waste left after clearcutting in *Pinus radiata* plantations in New Zealand. In deriving this methodology, they found that the number of logs intersected by transect lines and the total volume of pieces found were strongly correlated with one another. Therefore, the volume on a site could be estimated by counting the number of logs present. This led to faster estimates of residue volume. However, it is first necessary to test for bias in the orientation of residue pieces, which could skew results (Warren and Olsen 1964). Van Wagner (1968) improved the line intersect method by making it less sensitive to piece orientation, and a good estimator of residue volume in any form. He gave the equation:

$$V = \frac{\pi^2 \Sigma d^2}{8L} \qquad \textbf{(1)}$$

where: V = the volume of residue per unit area,

d = piece diameter,

L = length of the sample line;

all of which are in common units. To obtain volume in $ft^3/acre$ with diameter in inches and the length of the sample line in feet, the resulting volume from equation **(1)** must be multiplied by:

$$\frac{43{,}560 \ ft^2/acre}{144 \ inch^2/ft^2} \qquad \textbf{(2)}$$

The weight of residue is given by the following equation:

$$W = \frac{\Pi^2 S \Sigma d^2}{8L} \qquad \textbf{(3)}$$

where: W is the weight of residue per unit area,

S is the specific gravity;

both of which are in common units (Van Wagner 1968). The modified equation for determining residue in tons/acre becomes:

$$W = \frac{11.65 S \Sigma d^2}{L} \qquad \textbf{(4)}$$

The basic volume equation **(1)** relies on three assumptions. The first is that residue pieces are cylindrical. This assumption was first challenged by Van Wagner (1968), who felt that the presence of taper would not increase the error involved in volume estimations. Likewise, Pickford and Hazard (1978) found, in similar studies, that taper introduces little additional bias. However, populations of tapered pieces must be sampled much more intensively to reach the desired level of precision.

The second assumption is that pieces are horizontal (i.e. lying flat on the ground). As pieces are tilted, the chance that they will be crossed by sample lines decreases, and therefore volume estimates will be deflated. This may not be a problem since the error introduced by tilt is not significant at smaller angles (e.g., only 0.4 percent at 5 degrees) (Van Wagner 1968).

The third assumption is that residue pieces are randomly oriented. Error related to piece orientation can be

reduced by running several sampling lines in different random directions from sample points in areas where cutting practices or topography created residue orientation patterns (Van Wagner 1968, Howard and Ward 1972, Hazard and Pickford 1986).

These equations have been tested and refined by several researchers in varying field conditions. Bailey (1970) suggested that intersected piece volumes should be calculated as the mean cross-sectional area of the piece. However, in order to save time, he felt that the diameter at intersection of residue could be substituted for the mean cross-sectional area if a 25 percent subsample was taken where piece end areas were calculated. The reliability of the line intersect method also has been found to be little affected by species of residue, type of cut, slope, presence of logging roads, or the length of residue pieces; however, methodology can be altered to accommodate some of these extrinsic factors (Martin 1976).

One concern is the considerable sample effort needed to reach high levels of precision. It has been recommended that approximately 4,000 feet of line are needed to achieve confidence intervals narrower than ±25% at the 95% probability level (Pickford and Hazard 1978). However, even at these levels, line intersect methodology is more efficient than area sampling (Hazard and Pickford 1986). Researchers must weigh time and resources when deciding on the length of sampling line needed. Sampling time is directly related to residual volume and the type of cut (Martin 1976); therefore, sampling intensity may be best calculated in the field based on the prevailing conditions.

West Virginia Logged Area Analysis Methods: Line intersect methodology was used to quantify logging residue left in the woods following timber harvests in West Virginia. A total of 17 harvested sites were sampled within five of the six West Virginia Division of Forestry (WVDOF) districts during the summer of 1995 (Figure 1). Only 16 sites were visited in District 3, for a

total of 101 sites statewide. Harvests had to be at least 20 acres in size before they were considered. Each harvest site was selected randomly from all harvests conducted during 1993 and 1994 within each District. Harvest data were obtained from WVDOF notification forms.

At each harvested site, field workers identified the main log-landing area. From this point, they faced north and glanced at the second hand of a watch, and then proceeded three chains into the harvest in this random direction. If this path took them out of the harvested area, they obtained another random direction. Once they reached the first sampling point, the field workers faced north as before, and obtained a random direction from their watch. A 100 foot tape was used to define the transect line in that direction. Workers walked along the transect and recorded the species and diameter at intersection of every residue piece that crossed the line. After completing the first line, the field worker turned 90° to the east and ran a second 100 foot transect line from the sampling point, so there were two transect lines per point. Once both lines were sampled, field workers proceeded three chains in a random direction to the next sampling point where the next two 100 foot lines were placed. The number of sampling lines to be used on each harvest was obtained with a traditional sample size formula of the form:

$$N = \frac{CV^2 t^2}{DP^2} \qquad \textbf{(5)}$$

where: N = required number of 100 feet transects,

CV^2 = coefficient of variation for residue volume,

t^2 = Students t-value at 95% confidence level,

DP^2 = desired degrees of precision.

Volume estimates **(1)** based on diameters of residue at intersection were calculated after one full day in the field at each harvest site. The required number of sample lines was then calculated using these data. Crews were instructed to run at least 30 transect lines (3,000 feet) at each harvest, regardless of sample size calculations. Likewise, the maximum number of lines was limited to those that could be completed after 16 hours of field work. Only residue that was at least 4 inches in diameter at the point of intersection and at least 4 feet long was recorded in the field.

Along every third line an intensive sample was conducted so that a more accurate description of residue characteristics, including individual piece volume and size, could be obtained. On these lines, the species and diameter at intersection, as well as the small end diameter (to 4 inches), large end diameter, length of piece, and potential product were recorded. If applicable, residue on intensive lines was placed into one of the following product categories: pulpwood, sawlog, rail log, or peeler log. All pieces that were between 4 and 11 inches in diameter and ≥4 feet in length were recorded as pulpwood. A sawlog had to be greater than 8 feet long and at least 11 inches in diameter. Rail logs had to be between 5 and 11 inches in diameter, at least 11 feet in length and either yellow-poplar, spruce (*Picea* spp.), or hemlock (*Tsuga canadensis*). Yellow-poplar, cucumber magnolia (*Magnolia acuminata*), and sycamore (*Platanus occidentalis*) residue pieces that were between 8 and 30 inches in diameter and either 8 feet 10 inches, 17 feet 6 inches, 27 feet, or 35 feet in length were recorded as peeler logs.

Residue pieces crossed by line transects were broken into specific species groups for ease in computations. The following groups were used: **yellow-poplar; soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder

(*Acer negundo*); **white oak** - included white oak (*Quercus alba*) and chestnut oak (*Q. prinus*); **northern red oak** - included red oak (*Q. rubra*), scarlet oak (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), hemlock, and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), American beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafrass albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robina pseudoacacia*), and black gum (*Nyssa sylvatica*); and **other-hardwood** - which included tree of heaven (*Ailanthus altissima*), flowering dogwood (*Cornus florida*), American hornbeam (*Carpinus caroliniana*), hophornbeam (*Ostrya virginiana*), paw paw (*Asimina triloba*), *Viburnum* spp., and striped maple (*Acer pensylvanicum*).

Volume and weight estimates were calculated for each line using equations **1** and **4**. Weights were derived by associating specific gravities (USDA For. Serv. 1987) with individual species, not species groups (Table 1). Volumes of individual residue pieces crossed on intensive lines were calculated using Smalian's equation:

$$V = \frac{(A_1 + A_2)}{2} L \qquad \textbf{(6)}$$

where: A_1 = piece small-end area,

A_2 = piece large-end area.

Analysis of variance (ANOVA) was used to determine if differences existed among Districts in the amount of residue being left following timber harvests. Volume and weight estimates were averaged at the evaluation (harvest) level and then square root+1 transformed to help normalize their

distributions. The following ANOVA model was used:

$$y_{ij} = \mu + \alpha_i + \beta_{ij} + \varepsilon_{ij}$$

where: y_{ij} = volume/weight of residue at the evaluation level,

μ = overall volume/weight mean,

α_i = main effect of the *i*th level of District,

β_j = deviation from the mean caused by the *j*th level of evaluation,

ε_{ij} = random effect due to the individual evaluation.

An alpha level of 0.05 was used for all analyses.

RESULTS

The amount of residue remaining after harvest will be a direct result of the intensity of the logging operation. Residue volumes and weights varied greatly among the WVDOF Districts; as did harvesting intensity (Figure 2). Because harvests were picked at random, volume and weight estimates are considered a representative sample of those found throughout harvest sites in West Virginia.

A total of 3,284 lines were sampled in the six WVDOF Districts during the study period. Intensive lines accounted for 33% (1,088) of the total. On all lines, 7,638 pieces of residue were crossed, whereas on intensive lines, 2,401 pieces of residue were crossed. Transects in District 4 crossed the most residue, followed by District 3 and District 6 (Table 2). Residue was not crossed on 1,200 lines. Over 37 percent of the intensive lines did not cross residue.

On intensive lines, 2,162 pieces of residue were categorized as pulpwood, 204 met sawlog specifications, 18 met rail log and 17 met peeler log specifications (Table 3). District 5 had the most residual sawlogs, District 3 had the most residual rail logs and District 4 had the most residual peeler logs remaining after harvest (Table 3).

Statewide, the mean diameter of residue pieces at the point of intersection was 7.0 inches, ranging from 6.5 inches in District 2 to 7.2 inches in Districts 4 and 5. The mean diameter at intersection on the intensive subsample was similar; it ranged from 6.8 inches in District 2 to 7.4 inches in Districts 4 and 5 (Table 4). The overall mean diameter at intersection on intensive lines was 7.1 inches.

Volume estimates: The average volume of residue left on the ground after harvest in West Virginia was 504.4 ft^3/acre. There were differences among Districts in the total volume of residue remaining after harvest ($F = 13.49$, d.f. = 5, $p = 0.0001$). District 4 had significantly higher volume estimates than the other districts, with an average of 928.7 ft^3/acre of logging residue. District 4 was followed by Districts 6 and 3 with 591.3 and 549.0 ft^3/acre of logging residue after harvest, respectively. Residue estimates from Districts 6 and 3 were significantly greater than those from Districts 1, 2 and 5 (Table 5).

Of the species groups, red oak and white oak averaged the most volume per acre in the state (Table 6). The proportion of residue volume in each of the five major species groupings varied within each District (Figure 3). District 6 had the highest volume estimates of the white oak group with 272.7 ft^3/acre, which also was the greatest volume of any one species group in all six Districts (Table 7). District 4 had the greatest volume in the red oak group after harvesting, followed by Districts 6 and 3 (Figure 3). Mixed-hardwood volume estimates were greatest in District 4 with 253.9 ft^3/acre, followed by District 3 with

180.0 ft^3/acre. District 4 had the greatest volume estimates in both yellow-poplar and soft-hardwood residue after logging, with 196.5 and 104.6 ft^3/acre, respectively (Table 7).

Weight estimates: The average weight of logging residue found in West Virginia was 8.4 tons/acre. Weight estimates varied significantly among districts ($F = 13.11$, d.f. = 5, $p = 0.0001$). District 4 had significantly greater weight estimates than the remaining districts with an average of 15.0 tons/acre of logging residue followed by Districts 6 and 3 with 10.4 and 9.0 tons/acre, respectively. Residue weight estimates from Districts 6 and 3 were significantly greater than those in Districts 1, 2, and 5 (Table 8).

The red oak species group had the highest weight estimates with 2.52 tons/acre statewide. It was followed by the white oak and the mixed hardwood species groups with 2.22 and 2.02 tons/acre, respectively (Table 9). In all Districts, the red oak, white oak, and mixed hardwood species groups accounted for the highest residue weight estimates (Figure 4). District 6 had the greatest tonnage of white oak with 5.0 tons/acre, doubling that of District 4. District 4 had the greatest tonnage of red oak residue with 4.0 tons/acre, followed by Districts 6 and 3 with 3.7 and 2.4 tons/acre, respectively (Table 10). District 4 also had the highest estimated weight of mixed hardwood residue with 4.6 tons/acre. It was followed by Districts 3 and 5 with 3.1 and 1.7 tons/acre respectively. Yellow-poplar weights were the highest in District 4 with an estimated 2.5 tons/acre, more than double that of the next District. District 4 had the greatest soft-hardwood weight estimates, followed by Districts 3 and 1 (Table 10).

Intensive sample results: Results from intensive lines showed that the average individual residue piece volume was 12.9 ft^3. District 5 had the largest average piece size with an estimated volume of 17.4 ft^3, followed by District 1 with an average piece

size of 17.3 ft^3 and District 3 with an average piece size of 14.9 ft^3 (Table 11). Throughout the State, white oak residue pieces were the largest, with an average piece volume of 14.8 ft^3. White oak residue was followed by red oak and soft hardwood with average piece volumes of 13.8 and 13.2 ft^3, respectively (Table 12).

The majority of the residue encountered on intensive lines fell within pulpwood specifications. District 2 had the highest percentage of pulpwood at 100 percent. It was followed by Districts 6 and 1 with 93.8 and 92.4 percent, respectively (Table 13). In District 3, 30.4 percent of the residue crossed on intensive lines met sawlog specifications, followed by District 5 with 26.1 percent (Table 13). Sawlog volumes were not concentrated in any particular species group (Table 14). However, volume of oak sawlogs was greater than any other species in each District.

District 3 had the highest proportion of rail logs (1.2 percent). The remaining districts had less than 1 percent of their intensive sample that met rail log specifications (Table 13). As expected, peeler logs were not frequently encountered. However, of the residue crossed on intensive lines in District 4, 3.3 percent met peeler specifications. Less than 1 percent of the residue crossed in the remaining districts met peeler specifications.

DISCUSSION

Several important inferences can be made from the results of this study. On a Statewide basis, the results provide an indication as to how much roundwood could be supplied to new plants if it is all considered to be allocated to pulpwood, with the lowest product quality requirements. Assuming 180,000 acres are harvested annually in West Virginia with an average residue weight of 8.4 tons/acre, an additional 1.5 million tons of residue would be available each year for production. It is possible that pulpwood markets could benefit from the influx of this additional roundwood.

The large variations in the volume/weight among Districts could be traced, in part, to market availability (in terms of both market type and market size). Most of the residue is in pulpwood form, while only Districts 3 and 5 have any substantial sawlog volumes remaining after harvest. Other than species, there is no indication as to the quality of residual sawlogs. However, it is assumed that they are of poor quality/form.

Two of the most sought after species, red oak and white oak, are being left in greater volume than any other species. In contrast, yellow-poplar and soft-hardwood volumes are relatively low. The large volume of oak being left could be a result of its dominance throughout the State and/or its characteristic growth form (as compared to yellow-poplar), which would leave a greater amount of residue available per tree. However, it is possible that increased competition for yellow poplar and other soft hardwoods has improved utilization, particularly with competition from the recently established engineered wood products and composite panel producers.

Logging residue left after harvesting represents an often overlooked resource that can be utilized to offset removals from

the standing resource. Logging residue in West Virginia represent a major source of roundwood that is potentially available when demand and price reach a level that makes removal profitable.

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Table 1. Specific gravities used to calculate the weight of residue left after harvesting in West Virginia.

Species	Specific Gravity	Species	Specific Gravity
Acer negundo	0.40	*Magnolia fraseri*	0.45
Acer spp.	0.53	*Magnolia accuminata*	0.44
Acer pensylvanicum	0.49	*Magnolia* spp.	0.45
Acer saccharum	0.56	*Nyssa sylvatica*	0.46
Acer rubrum	0.49	*Ostrya virginiana*	0.63
Aesculus octandra	0.40	*Oxydendrum arboreum*	0.46
Ailianthus altissima	0.40	*Pinus* spp.	0.42
Amelanchier spp.	0.40	*Pinus rigida*	0.47
Asimina triloba	0.40	*Pinus strobus*	0.34
Betula alleghaniensis	0.40	*Pinus virginiana*	0.45
Betula spp.	0.60	*Platanus occidentalis*	0.46
Betula lenta	0.60	*Populus* spp.	0.36
Carya ovata	0.60	*Prunus serotina*	0.47
Carya spp.	0.62	*Quercus rubrum*	0.56
Carya tomentosa	0.64	*Quercus prinus*	0.57
Castanea dentata	0.47	*Quercus coccinea*	0.60
Celtis spp.	0.49	*Quercus velutina*	0.56
Cornus florida	0.60	*Quercus alba*	0.60
Fagus grandifolia	0.56	*Robina pseudoacacia*	0.66
Fraxinus spp.	0.55	*Sassafras albidum*	0.42
Fraxinus americana	0.55	*Tilia americana*	0.32
Juglans nigra	0.51	*Tsuga canadensis*	0.38
Juniperus virginiana	0.44	*Ulmus* spp.	0.47
Liriodendron tulipifera	0.40	*Viburnum* spp.	0.60

Table 2. Mean, standard deviation and maximum number of residue pieces crossed by transect lines during the summer of 1995 in West Virginia

	All Lines			Intensive Lines[a]		
District	Mean	STD	Max	Mean	STD	Max
1	2.5	2.8	19	2.3	2.3	13
2	1.7	1.4	9	1.6	1.5	8
3	2.9	2.4	13	2.7	2.1	10
4	4.2	2.7	17	3.8	2.3	10
5	2.2	2.3	16	2.2	2.4	13
6	2.8	2.6	22	3.0	2.9	22

[a] Every third transect was considered intensive. Residue length and large and small end diameter (to 4 inches) were measured on these lines.

Table 3. Number of residue pieces, by product category and District, crossed on intensive transect lines during the summer of 1995 in West Virginia.

District	Pulpwood	Saw Logs	Rail Logs	Peeler Logs
1	294	13	2	1
2	184	0	0	0
3	365	42	14	4
4	604	25	1	10
5	228	97	0	1
6	487	27	1	1
Totals	2,162	204	18	17

Table 4. Mean, standard deviation (STD) and maximum diameter at intersection of residue pieces crossed by transect lines during the summer of 1995 in West Virginia.

	All Lines			Intensive Lines[a]		
District	Mean	STD[b]	Max[c]	Mean	STD[b]	Max[c]
1	6.8	3.1	28.4	7.1	3.2	21.9
2	6.5	2.7	32.5	6.8	2.9	32.5
3	6.8	2.8	24.2	7.0	3.0	24.2
4	7.2	3.0	26.0	7.4	2.9	24.5
5	7.2	3.3	28.4	7.4	3.4	28.4
6	7.1	3.2	36.8	7.0	3.2	36.8
Statewide	7.0	3.0	36.8	7.1	3.1	36.8

[a] Every third transect was considered intensive. Residue length and large and small end diameter (to 4 inches) were measured on these lines.
[b] Standard Deviation
[c] Maximum diameter

Table 5. Mean volume of all residue pieces crossed by transect lines during the summer of 1995 in West Virginia Division of Forestry Districts.

District	N[a]	Volume[b]	STD[c]	CV[d]	Max[e]	Duncan[f]
1	558	395.2	734.0	185.7	5,484.1	C
2	514	211.3	403.0	190.7	4072.0	C
3	530	549.0	640.4	116.7	3,534.6	B
4	510	928.7	849.3	91.4	5,436.8	A
5	610	337.8	688.7	182.3	5,358.6	C
6	562	591.3	760.2	128.6	7,459.4	B
Statewide	3,284	504.4	727.7	144.3	7,459.4	

[a] Number of transect lines used in each district
[b] Mean volume of all residue in cubic feet/acre
[c] Standard Deviation
[d] Coefficient of Variation
[e] Maximum volume found on any one line within each district
[f] Duncan's grouping; means with same letter are not significantly different

Table 6. Mean volume estimates (ft^3/acre) of logging residue pieces crossed by transect lines during the summer of 1995 in West Virginia.

Species Group[a]	Mean Volume	STD[b]	CV[c]	Max[d]
Yellow-poplar	69.8	260.3	372.9	3,920.0
Soft hardwood	47.7	182.4	382.4	4,071.9
White oak	121.1	354.5	292.7	5,054.2
Red oak	143.7	383.9	267.2	4,403.2
Softwood	4.9	43.85	896.2	937.8
Mixed hardwood	116.1	332.9	286.7	3,929.2
Other hardwood	1.1	15.9	1,485.9	573.85

[a] **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. prinus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*), and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*), and eastern red cedar (*Juniperus virginiana*); **mixed hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), and black gum (*Nyssa sylvatica*); **other-hardwood** - which included *Ailanthus*, flowering dogwood (*Cornus florida*), American hornbeam (*Carpinus caroliniana*), hop hornbeam (*Ostrya virginiana*), paw paw (*Asimina triloba*), *Viburnum* spp., and striped maple (*Acer pensylvanicum*).

[b] Standard Deviation

[c] Coefficient of Variation

[d] Maximum volume

Table 7. Mean volume (ft^3/acre) of logging residue pieces, by District and species group, crossed by transect lines during the summer of 1995 in West Virginia Division of Forestry Districts.

	Mean Residue Volume By Species Group[a]					
District	Yellow-Poplar	Soft-hardwood	White oak	Red oak	Softwood	Mixed-hardwood
1	46.7	56.8	78.7	117.3	0.0	95.7
2	10.9	15.8	95.0	57.7	1.9	29.3
3	77.6	76.4	73.4	139.4	0.6	180.0
4	196.5	104.6	137.8	231.5	2.8	253.9
5	71.9	18.9	70.0	111.1	6.7	97.5
6	21.9	20.4	272.7	208.3	16.5	50.7

[a] **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. primus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*), and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), and black gum (*Nyssa sylvatica*).

Table 8. Mean weight of all residue pieces crossed by transect lines during the summer of 1995 in West Virginia Division of Forestry Districts.

District	N[a]	Weight[b]	STD[c]	CV[d]	Max[e]	Duncan[f]
1	558	6.5	12.5	190.8	98.3	C D
2	514	3.7	6.9	188.7	62.4	D
3	530	9.0	10.7	119.3	60.0	B
4	510	15.0	13.9	92.6	92.8	A
5	610	6.2	11.6	185.6	93.4	C D
6	562	10.4	13.6	131.0	131.7	B C
Statewide	3,284	8.4	12.3	146.4	131.7	

[a] Number of transect lines used in each district
[b] Mean weight of all residue in tons/acre based on specific gravity green
[c] Standard Deviation
[d] Coefficient of Variation
[e] Maximum weight found on any one line within each district.
[f] Duncan's grouping; means with the same letter are not significantly different.

Table 9. Mean weight estimates (tons/acre) of species-specific logging residue pieces crossed by transect lines during the summer of 1995 in West Virginia.

Species Group[a]	Mean Weight	STD[b]	CV[c]	Max[d]
Yellow-poplar	0.87	3.25	372.90	48.94
Soft hardwood	0.69	2.61	380.07	62.28
White oak	2.22	6.49	293.20	94.66
Red oak	2.52	6.76	267.25	76.97
Softwood	0.07	0.62	902.17	12.29
Mixed hardwood	2.02	5.82	288.25	70.80
Other hardwood	0.02	0.21	1,395.0	7.17

[a] **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. primus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*) and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), and black gum (*Nyssa sylvatica*); **other-hardwood** - which included *Ailianthus*, flower dogwood (*Cornus florida*), American hornbeam (*Carpinus caroliniana*), hop hornbeam (*Ostrya virginiana*), paw paw (*Asimina triloba*), *Viburnum* spp., and striped maple (*Acer pensylvanicum*).

[b] Standard Deviation

[c] Coefficient of Variation

[d] Maximum weight

Table 10. Mean weight (tons/acre) of logging residue pieces, by District and species group, crossed by transect lines during the summer of 1995 in West Virginia.

District	Mean Residue Weight By Species Group[a]					
	Yellow-poplar	Soft-hardwood	White oak	Red oak	Softwood	Mixed-hardwood
1	0.6	0.9	1.4	2.1	0.00	1.6
2	0.1	0.2	1.7	1.0	0.02	0.5
3	1.0	1.1	1.3	2.4	0.01	3.1
4	2.5	1.4	2.5	4.0	0.03	4.6
5	0.9	0.3	1.3	2.0	0.09	1.7
6	0.3	0.3	5.0	3.7	0.25	0.9

[a] **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. primus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*), and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robina pseudacacia*), and black gum (*Nyssa sylvatica*).

Table 11. Mean volume of individual residue pieces crossed by transect lines during the summer of 1995 in West Virginia Division of Forestry Districts.

District	N[a]	Volume[b]	STD[c]	CV[d]	Max[e]
1	310	17.3	17.9	103.1	81.0
2	184	7.6	14.6	191.4	184.4
3	425	14.9	24.9	167.7	204.9
4	640	6.4	8.5	132.3	78.5
5	325	17.4	19.5	112.3	132.4
6	516	13.8	21.4	154.9	345.3
Statewide	2,400	12.9	18.9	151.0	345.3

[a] Number of residue pieces crossed in each district on intensive lines
[b] Mean volume of residue in cubic feet
[c] Standard Deviation
[d] Coefficient of Variation
[e] Maximum volume of any one piece within each district

Table 12. Mean volume estimates (ft^3) of individual residue pieces found in West Virginia following timber harvests.

Species Group[a]	Mean Volume	STD[b]	CV[c]	Max[d]
Yellow-poplar	9.36	10.29	110.04	71.55
Soft hardwood	13.19	22.40	169.73	184.37
White oak	14.80	20.66	139.60	204.91
Red oak	13.77	21.74	157.82	345.30
Softwood	4.65	5.42	116.73	22.61
Mixed hardwood	10.33	14.38	139.26	128.33

a **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*) aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. primus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*), and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), and black gum (*Nyssa sylvatica*).

[b] Standard Deviation

[c] Coefficient of Variation

[d] Maximum volume

Table 13. Percentage of residue found in each product category during the summer of 1995 in West Virginia.

District	Pulpwood[a]	Saw Logs[b]	Rail Logs[c]	Peeler Logs[d]
1	92.4	7.4	<1	<1
2	100.0	0.0	0	0
3	69.0	30.4	1.2	<1
4	87.2	9.8	<1	3.3
5	73.7	26.1	0	<1
6	93.8	5.7	<1	<1

[a] Any residue crossed by transect that was at least 8' in length and 4" in diameter.

[b] Residue that was at least 11" in diameter and ≥8' in length.

[c] Yellow-poplar, spruce, hemlock and pine residue that was between 5'-11" in diameter and at least 11" in length.

[d] Yellow-poplar, cucumber magnolia and sycamore residue that was between 8"-30" in diameter and either 8'10", 17'6", 27', or 35' in length.

Table 14. Percentage of total sawlog volume (ft^3/acre) in each species group for logs crossed on intensive lines during the summer of 1995 in West Virginia.

	District					
Species Group[a]	**1**	**2**	**3**	**4**	**5**	**6**
Mixed Hardwood	22	0	12	15	26	6
Red Oak	35	0	25	30	29	41
Soft Hardwood	7	0	32	5	3	6
White Oak	13	0	1	0	26	0
Yellow-Poplar	23	0	1	0	26	0
Softwood	0	0	0	0	1	0

a **Yellow-poplar** includes only yellow-poplar; **soft-hardwood** - included *Magnolia* spp., red maple (*Acer rubrum*), American basswood (*Tilia americana*), aspen (*Populus* spp.), and box elder (*Acer negundo*); **white oak** - included white (*Quercus alba*) and chestnut oaks (*Q. primus*); **red oak** - included red (*Q. rubra*), scarlet (*Q. coccinea*) and black oak (*Q. velutina*); **softwood** - included pines (*Pinus* spp.), eastern hemlock (*Tsuga canadensis*), and eastern red cedar (*Juniperus virginiana*); **mixed-hardwood** - included hickory (*Carya* spp.), cherry (*Prunus* spp.), beech (*Fagus grandifolia*), sugar maple (*A. saccharum*), sassafras (*Sassafras albidum*), sourwood (*Oxydendrum arboreum*), white ash (*Fraxinus americana*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), and black gum (*Nyssa sylvatica*).

Figure 1. West Virginia Division of Forestry Districts.

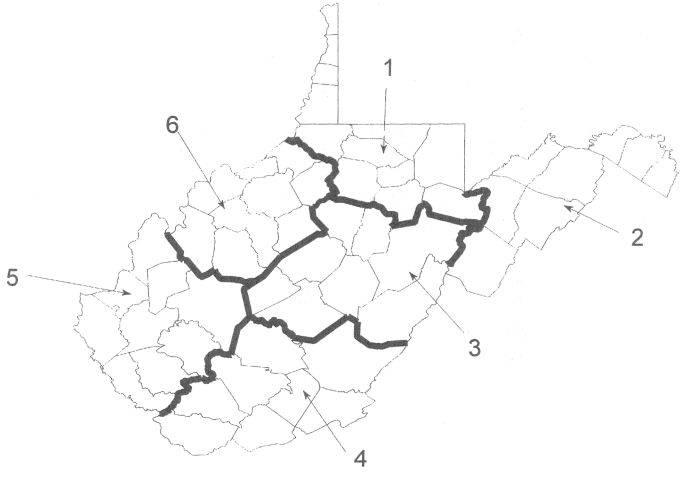


Figure 2. Number of 1993 and 1994 timber harvests in West Virginia by basal area removal class in 1993 and 1994

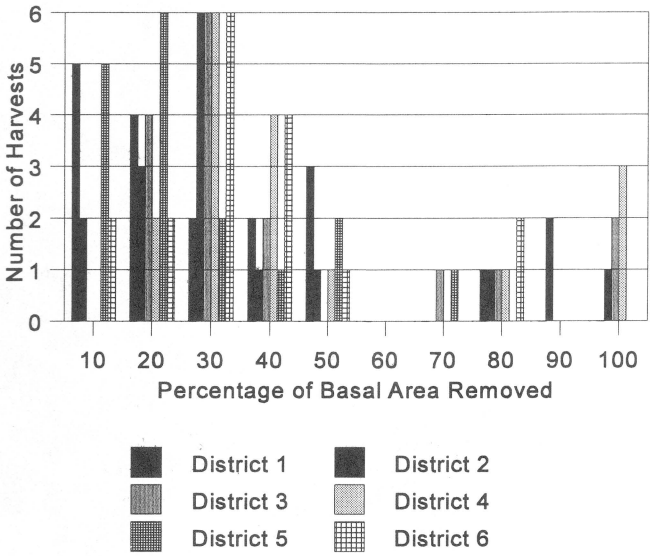


Figure 3: Residue Volumes (ft^3/acre) by West Virginia Division of Forestry District.

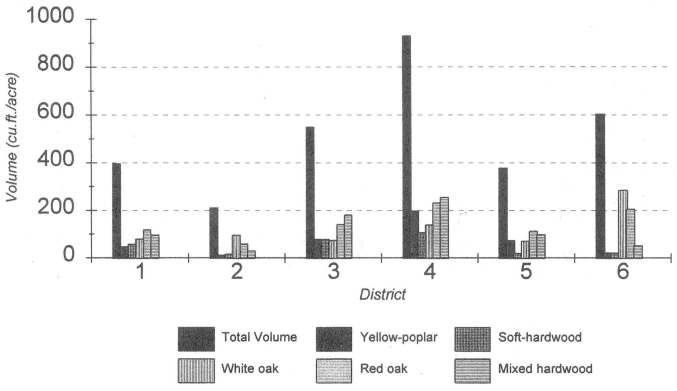
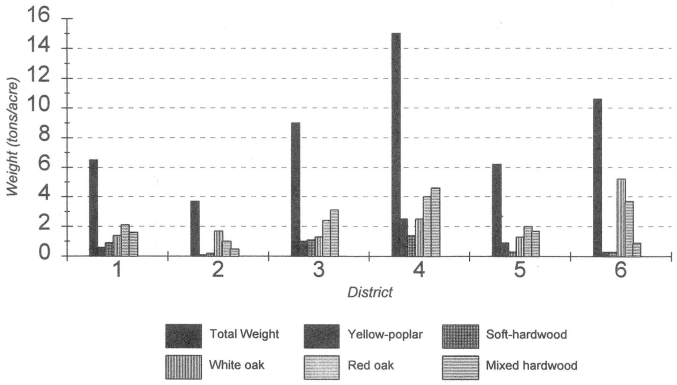


Figure 4: Residue Weights (tons/acre) by West Virginia Division of Forestry District.



NOTES

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