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Logging Residue in Southeast Alaska

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Abstract

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Detailed information on logging residues in southeast Alaska is provided as input to economic and technical assessments of its use for products or site amenities. Two types of information are presented. Ratios are presented that can be used to generate an estimate, based on volume or acres harvested, of the cubic-foot volume of residue for any particular area of southeast Alaska. Separate ratios are given for live and dead or cull material, and for net and gross volume. Tables display per-acre residue volume by various characteristics that might affect either use or disposition. These tables show net or gross volume, or both, by diameter and length classes, by origin, by percentage of soundness, by degree of slopes and distance to roads, and by number of pieces of residue per acre.

Keywords: Southeast Alaska, logging residue, slash, residue estimation, fuel wood, residue management.

Summary

A large volume of woody biomass has traditionally remained on site after logging in southeast Alaska. Interest is growing in this material for energy and conventional products, as well as for its environmental attributes. A great deal of information is needed on the volume and characteristics of residue to adequately address these options. Existing sources were out of date and did not provide the information needed to make site-specific assessments for southeast Alaska. This study provides the capability to estimate the volume and characteristics of logging residue throughout southeast Alaska.

This study had two objectives. The first was to develop ratios for use in estimating the volume of logging residue for any area in southeast Alaska. These ratios relate the quantity of residue to timber harvest volume or harvested acres. Study results show, for example, an average net volume of logging residue (wood only) of 79 to 109 cubic feet per thousand board feet of harvest and an average gross volume ranging from 125 to 158 cubic feet per thousand board feet of harvest. The second objective was to provide data characterizing logging residue in ways that might affect its utilization for various products or its management for environmental considerations, A total of 57 clearcut units were sampled on public and private lands to meet the stated objectives. These samples were allocated to two land ownership strata, public and private. Only areas harvested after January 1984 were included.

Results are shown for each of the strata. Ratios for estimating residue volume are given for net and gross volume (cubic feet per thousand board feet of timber harvested or per acre of harvest) by live and dead or cull material and for wood only and for wood and bark. Information is also given on the volume of residue in large piles. Tables are provided that show the volume of residue by diameter and length classes, by origin of the material, by percentage of soundness, by degree of slope and distance to roads, and for number of pieces per acre. An example of how this information might be used to determine the volume of residue available for use at a particular location is also given.

Contents

Introduction

More than 57 percent (about 11 million acres) of the total land area in southeast Alaska is forested. The available timberland supports more than 26 billion cubic feet of wood, an important reason why strong interest in using woody material in Alaska as an alternative fuel for energy production continues. This is manifested by a number of sites currently being examined for power-generation opportunities. In some places, Haines, for example, construction of power-generating facilities is complete. The strength of this substantial activity can be partly attributed to a growing demand for electricity; potentially favorable rates of return from an investment in cogeneration facilities by wood-using industries, with options to sell excess power; and large supplies of wood and wood residues potentially being available for fuel.

One source of woody material receiving much attention is logging residue.[1] This underused resource apparently represents a significant opportunity to increase the flow of wood products from the forests of southeast Alaska. Besides being a large quantity of potentially usable wood fiber, logging residue (used for energy) has the added advantage of possibly mitigating some forest management problems associated with residue.

As is true throughout the West, a considerable volume of residue remains on a site after timber harvest in southeast Alaska. The amount of material on a particular harvest area or for a given year is directly related to economic conditions and export markets. Much of the material is small-tops and branches, for example--or from trees that were dead at the time of harvest, and is not part of the harvest contract. Regardless of the source, an understanding of the amount and characteristics of the material is important to decisions concerning utilization or onsite retention to enhance other resource values.

Comprehensive, up-to-date data for logging residue in Alaska are lacking, however. The most recent statewide statistics were reported in 1962 (Bones 1962). In addition to being outdated, these data are not in a form allowing for site-specific estimates of residue volume to be tied to current or future timber harvest. This capability is particularly important in light of the numerous sites throughout Alaska that are, or may be, considered for power generation, including cogeneration options. For the economic and technical feasibility of using logging residue to be evaluated, more detailed information about the characteristics of residue materials is needed than exists in the 1962 data. Crucial questions about costs, equipment, handling, and transportation require a data base providing information about size, number of pieces, distribution and quality of these materials. Although this type of information may exist for some areas and owners, no compatible data are available that are applicable to all lands where timber harvesting occurs. Also, existing data sources are based on differing standards, definitions, and sampling designs-critical elements in comprehensive, large-scale feasibility studies.

[1] See glossary for terms used in this report.

This study is designed to meet the needs of site-specific analyses of logging residue throughout southeast Alaska. The development of reliable, uniform data will enable the forest products and power-generating industries to gauge the economic feasibility of accelerating the use of logging residue for energy. An additional benefit is to provide parity in residue information with other Western States, thereby aiding regional energy planning and development efforts.

The study had two primary objectives. The first was to develop appropriate analytical tools for estimating the volume of logging residue for any uniquely defined supply zone in southeast Alaska. Volume estimators (ratios) developed in this study relate residue volume to both volume and acreage of timber harvest. One ratio gives the cubic-foot volume of residues associated with the harvest of 1,000 board feet of timber (CF/MBF). The other ratio gives cubic-foot volume of residue per acre harvested (CF/AC). An example is provided to demonstrate practical application of these ratios.

The second objective was to describe and classify logging residue by the following characteristics that might affect its use:

1. Gross and net volume, by diameter and length classes, for live and for dead or cull material.

2. Number of pieces per acre, by diameter and length classes.

3. Volume by percentage of sound (chippable) wood, in cubic feet per acre.

4. Accessibility on cutover areas, by slope and distance to road.

5. Origin of residue material, relative to felling and yarding practices.

In southeast Alaska, all information on residue is displayed for two strata based on land ownership. These strata were selected on the basis of differences in residue volume associated with harvesting methods and existing information on residue characteristics (Bones 1962). Results are based on measurements of logging residue completed during 1987 on 57 cutover units.

Methodology

Design of this study required the following steps: (1) determining sample size and allocation and selecting cutover areas to be sampled, (2) establishing procedures for sampling residue volume and characteristics, and (3) selecting procedures for computing ratios and characteristics of residue volume. Each of these steps is discussed below.

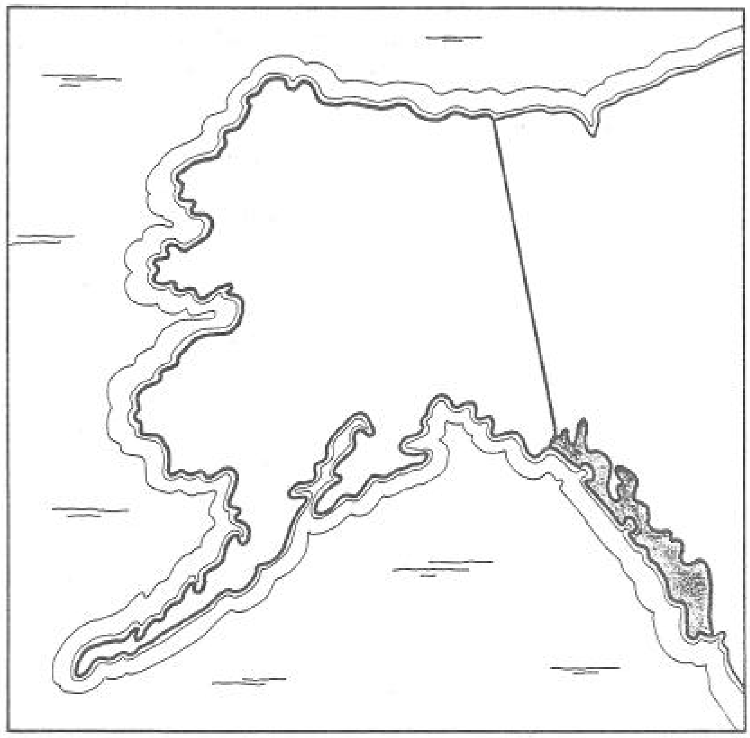


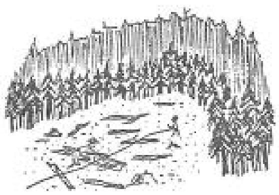
Figure 1-State of Alaska with southeast area highlighted.

Sample Size and Allocation

Sample stratification was based on timber ownership. Analysis of harvest data indicated that two significant classes of ownership exist in southeast Alaska, public and private. Practically all the timber harvest from public lands occurs in the Tongass National Forest, and most of the private harvest comes from Native Regional and Village Corporation lands. Not enough timber was harvested in any other ownership class to warrant a separate stratum. Clearcutting accounts for most timber harvesting in southeast Alaska; thus, this was the only harvest method included in the study. The study was confined to southeast Alaska (fig. 1), which accounted for more than 90 percent of the statewide timber harvest in 1987.

After the study strata were identified, the next step was to determine sample size for each stratum. Little information was available to base sample size decisions on. In particular, reliable statistical information for computing sample size, such as coefficient of variation, was not available. The areas having residue volumes closest to that expected in southeast Alaska are the coastal regions of Oregon and Washington (Howard 1981). Based on experience gained from study of those areas, a target of 30 samples per stratum was selected. We expected that this number of samples would yield an estimate of average residue volume of ± 20 percent of the true average 9 times out of 10. As will be seen later, the final precision achieved in the study exceeded the desired level. Because of some logistical factors, the final number of samples in each stratum was slightly less than the target number. The final sample size for each stratum was public-29 and private-28.

Sample Selection



Specific cutover areas were selected after the sample size for each stratum was determined. The first task was to identify all cutover areas (the sample population) by stratum. The desired number of samples was selected from this population.

The overall sampling scheme for the study was a two-stage sample, with PPS (probability proportional to size) sampling for the first stage. The second stage, residue sampling on each cutover unit, will be discussed later. In the first stage, PPS sampling was done for each of the two strata.

Following PPS sampling procedures, all qualifying cutover units were listed along with acres harvested. These acreages were accumulated, and random numbers were used to select specific units for sampling. With this procedure, larger cutover areas have a greater chance of being selected because each acre, in effect, has equal weight. Because sampling was done with replacement, some cutover units were selected more than once. For these units, residue measurements were made once, then replicated for each additional time the unit was selected.

The sample population was determined by obtaining a list of all areas cut during the study period, January 1, 1984, to September 30, 1985, for each owner group. Sample units were selected from the lists provided by landowners.

All cutover areas selected had to meet five criteria to be considered for study:

1. Logging was completed after January 1, 1984, and before September 30, 1985.
2. The unit was 5 acres or larger.
3. Residue on the unit had not been burned after logging.
4. The unit was not a fire salvage sale.
5. Logging residue on the unit had not been utilized by cull log salvagers, firewood cutters, or secondary operators.

These criteria were established to ensure that residue estimates would be representative of normal harvesting. A larger number of sample units was selected than was dictated by the sampling process described. The extra units served as alternates to replace areas failing to meet study criteria during field examination. Alternate sample units for each stratum were used in the order they were drawn in.

After each of the cutover areas to be sampled was identified, the owners were contacted and asked to provide maps, location data, and information on characteristics of the area. Specific information was collected for each sample:

1. Age of the timber harvested.
2. Acres of each area harvested.
3. Type of logging equipment used.

4. Percentage of contribution by the three major species harvested (set to 100 percent).

5. Volume of timber harvested, in thousand board feet per acre.

Residua Sampling Techniques

The average volume of residue on each cutover area was derived by three procedures. The line-intersect method was used to obtain an estimate for scattered materials and small piles (Howard and Ward 1972). A pile-volume estimator, obtained from a separate study, was used to determine the volume in large piles (Little 1982). The volume of bark was derived by using bark-to-wood factors obtained from a companion study (Spell and Max 1982). Information on characteristics of the residue was derived from a subsample of pieces measured for volume estimation.

Estimating scattered residue-The line-intersect method was used to estimate the volume of all residue material 3.01 inches in diameter inside bark (d.i.b.) and larger, 1.0 foot in length and longer, and not found in large piles. The line-intersect method has been widely used for estimating residue, and has been demonstrated to be efficient and unbiased (Pickford and Hazard 1978).

The sample design used in this study consisted of 200-foot line transacts located at each of 30 points on a systematic grid (fig. 2). The interval between grid points varied with size of the cutover area. Both the initial starting point and the base line for the grid system were randomly selected to reduce bias. To reduce bias associated with piece orientation, each of the 30 line transects was randomly oriented along 45-degree azimuths (Howard and Ward 1972).

All qualifying residue intersected by the 200-foot line transects was measured. Only pieces at least 3.01 inches d.i.b. and 1.0 foot long were considered measurable. Older dead pieces that were rotten to the point of losing their original form were excluded (fig. 3).

Measurements recorded for **each** piece of residue were:

1. Diameter (by 2-inch class) inside bark at the point of intersection with a transect line.

2. Net chippable content (estimated to nearest 20 percent) at the point of intersection with a transect line.

3. Whether the piece was live, or dead or cull of harvest.

These are the only measurements required to provide an estimate of gross and net volumes of scattered logging residue and small piles for a specific cutover area.

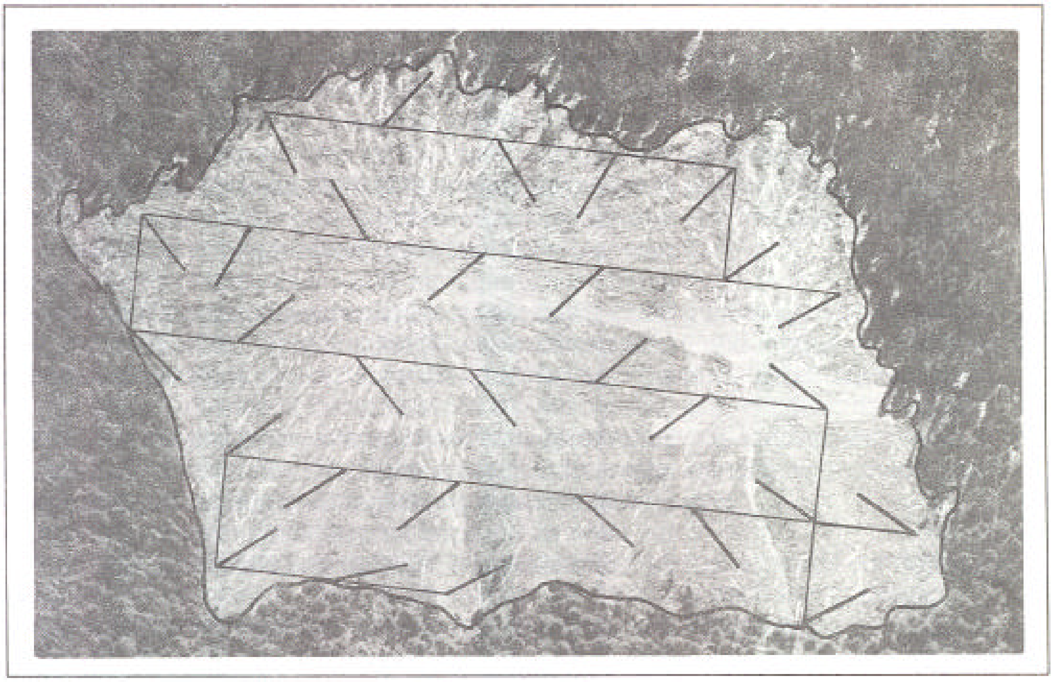


Figure 2-Example of sampling grid for a cutover area.

Figure 3-Deteriorated logs as such as this were not included in the study.

Figure 4-Large piles of residue such as this required separate procedures for estimating volume.

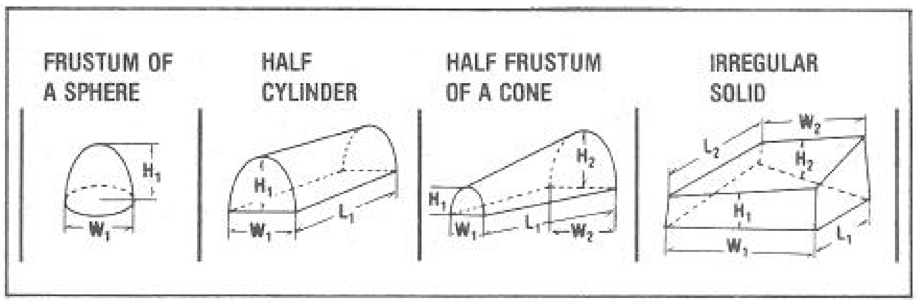


Figure 5-Geometric solids and related dimensions used for Estimating the volume of residue in large piles.

Estimating pile volume-The line-intersect method cannot be used to estimate residue in large piles (fig. 4) because many pieces in the interior of such piles are impossible to observe without taking the pile apart. Because destructive sampling of piles was not within the scope of this study, a separate two-step procedure was used to estimate pile volume. First, each pile was visually classified as one of four geometric solids (fig. 5). Then the dimensions appropriate for the selected shape were recorded to the nearest foot. The geometric volume of each pile was computed from these measurements and converted to solid-wood content according to procedures described by Little (1982).

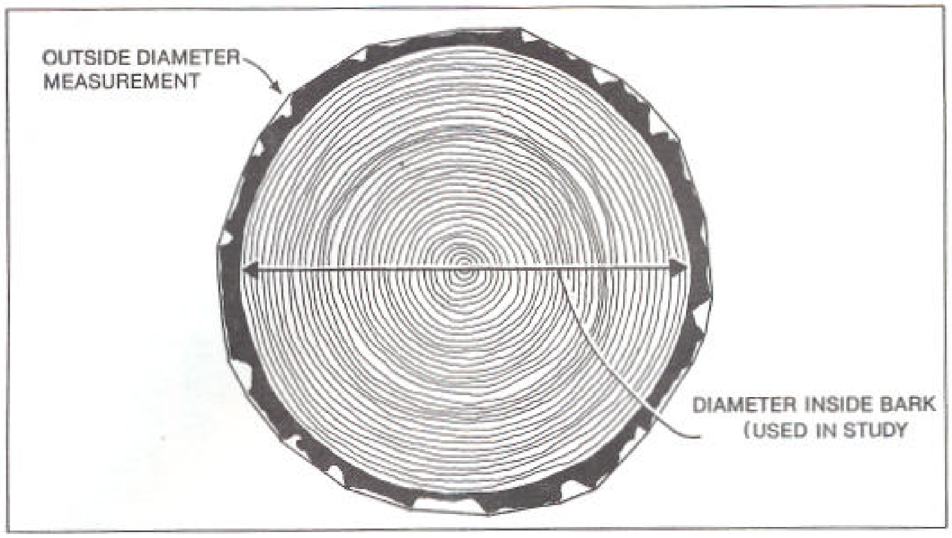


Figure 6-Voids associated with irregularities in bark were avoided by making inside-bark measurements.

Net (chippable) volume and origin of residue in large piles had to be derived by other means. Net volume was calculated by using data from an earlier study (Howard 1981) of residue from the harvest of old-growth timber with characteristics generally similar to those found in this study. The proportion of net volume to gross volume (0.54) from the 1981 study was applied to the gross residue volume of each pile to obtain net volume. The proportion of live, or dead or cull material in each pile was estimated by field personnel.

Estimating bark volume-Diameters of residue pieces were measured inside the bark to avoid problems associated with voids when outside-bark measurements are taken (fig. 6). Bark is an important raw material, however, particularly for energy conversion. Thus another method was required to estimate bark volume. Ratios of bark to-wood were developed for the major species and were based on data from a study of bark samples from 50 cutover areas in Idaho, Oregon, and Washington (Snell and Max 1982). A weighted average bark factor was computed for each sample unit by using harvest volume by species. These ratios were applied to wood residue volume to generate estimates of wood and bark volume.

Estimating residue characteristics-To provide data on size and number of pieces, additional measurements were made on a subsample of all residue pieces measured to estimate volume. The subsample consisted of all residue pieces encountered on the first 40 feet of each 200-foot line transect. This resulted in a subsample of 20 percent of the total number of pieces measured for volume. The measurements for pieces in the subsample were:

1. Diameter (d.i.b.) at intersection with line transect.

2. Small-end diameter (d.i.b.) to the nearest inch.

3. Large-end diameter (d.i.b.) to the nearest inch.
4. Length to the nearest foot.
5. Net chippable content.
6. Live, or dead or cull at time of logging.
7. Origin of the piece.

Subsample items 1.5, and 6 were the same measurements recorded for the linetransect volume estimate.

After the transact measurements were completed, all residue, including large piles, was visually classified by the following slope and distance-to-road categories:

Slope: 0-35 percent
over 35 percent

Distance to road: 0-500 feet
501-1,000 feet
over 1,000 feet

Roads were defined as any roadbed capable of handling log trucks and other logging equipment. In tractor-logged areas, especially those with flat terrain, acceptable roads are frequently of lower quality than those associated with steeper slopes.

Computational Procedures

The volume of residue recorded by the line-intersect method was computed by the following formula:

$$V = \frac{\pi^2 D^2}{8L} \times \frac{43,560}{144},$$

where V = volume of each piece of residue in cubic feet per acre (CF/AC);

D = diameter inside bark, in inches, of each piece of residue; and

L = total length of transect lines (6,000 feet).

The sum of the computed transect volume for each piece yields average gross volume (CF/AC) of residue for a specific cutover area. As discussed above, the volume of piles, where present, was computed separately. To estimate the average of wood in piles per acre, the total volume of residue in piles for each sample area was divided by the acreage of the area. This figure was added to the transect volume to obtain the total gross wood residue volume for each cutover area. Estimates of residue including bark were derived by applying the bark-to-wood ratios described above. Net chippable volume was computed from information collected for each piece tallied along the transects and from the pile-estimation process described earlier.

These computations provided estimates of residue in cubic feat per acre. A major objective of this study was, however, to provide ratios of cubic feet of residue to 1,000 board feet of timber harvested (CF/MBF). To obtain this ratio for a particular cutover area, the average volume of residue (CF/AC) was divided by the average harvest volume (MBF/AC). This is shown by:

$$\text{Ratio}_i = \frac{(\text{residue volume})_i}{(\text{harvest volume})_i} = \frac{(\text{CF/AC})_i}{(\text{MBF/AC})_i} = (\text{CF/MBF})_i \,,$$

where i =ith cutover area (sample unit).

Estimating average residue volume for a specific stratum required a further computational step. The use of PPS sampling, described earlier, results in the CF/AC volume of each unit having equal weight. The estimate for each stratum, therefore, is the arithmetic average of all units in the stratum. This is represented by the following formula:

$$\text{CF/AC}_j = \frac{\sum_{i=1}^{n} a_{ij}}{n} \,,$$

where ail = per-acre residue volume for i$^{u'}$ sample in j$^{u'}$ stratum, and

n = number of sample units in jth stratum.

The CF/MBF ratio for a stratum is similarly computed by using a ratio-of-the-means approach. The formula for computing the ratio for a specific stratum is represented by:

$$\text{Ratio}_j = \frac{\dfrac{\sum_{i=1}^{n} a_{ij}}{n}}{\dfrac{\sum_{i=1}^{n} h_{ij}}{n}} \,,$$

where aij and n are as defined above for CF/ACI, and

hij = per-acre harvest volume for 1 ' sample unit in jth stratum.

Computing the volume for characterization of residue is based on subsample measurements. The volume of each subsample piece is the same as that used for estimating the volume of the unit (CF/AC).

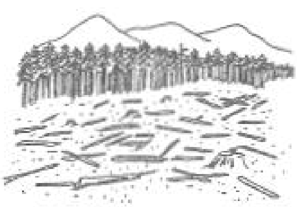
The gross volume of all pieces was summarized by small-end and large-end diameter and length classes for each cutover area. A proportion was developed to relate the accumulated subsample volume to the total volume estimated from the lire transects. This proportion was used to adjust the subsample volume in each diameter and length class to reflect the computed residue volume for each cutover area. To obtain number of pieces per acre by diameter and length classes, the adjusted volume for each class was divided by the average piece volume for the class.

Net chippable volume for residue characterization was computed by using gross volume and adjusted by the net chippable content percentage (item 5 of the subsample measurements).

Stratum averages of residue characteristics were computed in a manner similar to that described above. In effect, residue characteristics were developed by using all subsample pieces in each stratum and the average volume estimate for that stratum.

Study Results

Residue Volume Estimators



Ratios for estimating logging residue volume in southeast Alaska are presented in two forms. One ratio relates the cubic-foot volume of residue per thousand board feet of timber harvested (CF/MBF). The other gives residue volume in terms of cubic feet per acre harvested (CF/AC). Both ratios are useful, but their application depends on the type of analysis being made and the supporting data available to the user. Estimates of residue volume for a specific geographic area can be made by applying the appropriate ratio to timber harvest volume or acreage cut for each stratum in the area. A wide range of uses can be made of the tables in this report, which show gross and net volumes of residue with and without bark and live versus dead or cull material.

Conversions for metric, wood density, and higher heating values for selected species are shown in the appendix.

It is critical for the user to understand that estimates based on data from this report will indicate only the existence of residue material immediately alter harvest, for the particular set of economic and technical circumstances existing during the study period; **all estimates, other than those based on average stratum values, are subject to an undefined sampling error**. The availability of the residue for conversion to energy, pulp, or other products depends on several factors; for example, competing uses, intent of the landowner, environmental concerns, and cost. Other factors influence the accumulation of residue, but their identification is beyond the scope of this report. The user is responsible for determining the volume of residue that can be considered physically and economically available.

Table 1—Average gross and net volume of logging residue, per thousand board feet of harvest, by wood only and by wood and bark, by stratum

Stratum	Wood only Gross	Wood only Net	Wood and bark Gross	Wood and bark Net
	Cubic feet per thousand board feet			
Public	125	79	143	97
Private	158	109	182	133

Ratios of residue volume to harvest volume-Table 1 presents ratios of residue volume to harvest volume for gross and net volume of residue, with and without bark, for each study stratum. Often, particularly for future periods, timber harvest data are the most readily available base for estimates of residue volume. By applying the ratios in table 1 to timber harvest volumes, an estimate of residue volume can be obtained for a specific geographic area. A separate ratio and timber harvest figure should be used for each stratum represented in the area the residue assessment is being made for. These ratios, and other data in this report, are representative of harvesting practices and markets existing during the study and will remain useful as long as harvesting technology, stand conditions, and the markets do not change significantly.

The net volumes shown in table 1 represent the chippable portion of the residue, or that considered usable for fiber-based products. Defects like cracks, checks, or early stages of rot may make the material unusable for solid wood products (Farr and others 1976). Whatever product is considered, some unusable material may have to be removed to recover the desired portions.

Gross volume represents the mass of logging residue and is based on external dimensions of the residue. This volume measurement includes space not occupied by wood fiber, such as hollow logs (fig. 7) and pieces with splinters or chunks missing. Gross volume also includes material too rotten to have significant product value. An extreme example of this is a piece with gross volume but no chippable volume. Gross volume is an especially important measure of residue because it represents the overall physical quantity of material existing in a harvest area. Although the net volume of residue represents product quality and value, it is the gross volume that must be handled to recover the usable portions. Estimates of gross volume of residue are also important for determining equipment requirements and the cost of handling and transportation.

The amount and size of residual material are closely linked to many timber and land management issues and are important considerations in the broad context of residue management. Logging residue is, for example, strongly correlated to reforestation, esthetics, environmental quality, wildlife habitat, stand management activities, and fire hazard. As such, it may be a source of additional wood fiber or a potential impediment to mobility; or it may provide small game habitat and seedling protection and be a source of nutrients for future productivity.

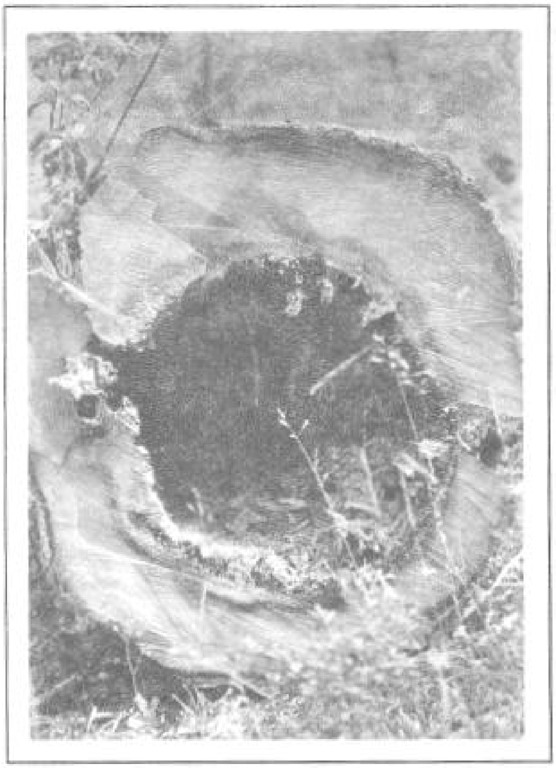


Figure 7-Hollow logs such as this have a gross volume, represented by external dimensions, that includes space containing no usable wood fiber.

Table 1 shows that the percentage of net volume to gross volume is slightly higher for private lands than for public lands, 69 versus 63 percent. This higher figure may not necessarily mean that the average piece of residue on private land is more sound; this difference might be attributable to a larger proportion of smaller, sound logs. The latter possibility could be significant because recovering completely sound small logs may be more economical than recovering partially defective larger !cgs. Data from tables shown later in this report can be used to evaluate this situation.

Ratios of residue volume to area harvested-Ratios of cubic feet of residue to acres harvested are also valuable expressions of the quantity of logging residue. When no timber harvest volume figures are available, or acreage figures are more accurate, these ratios can be used to derive estimates of residue volume much in the manner described above. Per-acre volume is especially useful for making economic assessments and for evaluating residue management alternatives. Table 2 gives the average gross and net residue volume per acre, by stratum, for wood only and for wood and bark.

Table 2—Average gross and net volume of logging residue, per acre, by wood only and by wood and bark, by stratum

	Wood only		Wood and bark	
Stratum	Gross	Net	Gross	Net
	Cubic feet per acre			
Public	4,011	2,539	4,602	3,130
Private	5,377	3,703	6,176	4,502

Table 3—Average gross and net volume of logging residue (wood only) by live or dead and cull material,[a] by stratum

	Gross		Net	
Stratum	Live	Dead/cull	Live	Dead/cull
	Cubic feet per acre			
Public	1,737	2,274	1,439	1,100
Private	2,847	2,530	2,469	1,234

[a] Includes the volume of residue in large piles.

As these data show, a significant opportunity for additional recovery of woody biomass from clearcuts seems to exist in southeast Alaska. This recovery may occur during or after initial harvesting, but regardless of the timing, the per-acre volumes should be high enough to encourage future utilization as market conditions change.

Not all residue material results from harvesting of live trees. Much of the residue comes from trees that were dead or cull at the time of logging. Some dead and cull trees, or portions of these trees, are marketed during harvest. A high percentage, however, are left on the ground because of defect or other quality considerations. As a result, dead and cull trees constitute a higher proportion of total residue than do live trees (table 3).

The potential effect of defect on marketability of dead and cull trees can be seen in table 3. A comparison of net volume to gross volume for live versus dead and cull shows the live trees to be about 85 percent sound and the dead and cull trees to be only 48 percent sound. The opportunity for economic recovery is obviously greater for the live portion than for the dead and cull residue. Likewise, the opportunities for recovery may be greater on private lands where the volume of live residue is highest.

Table 4—Average gross and net volume of logging residue (wood only) by origin of material, by stratum[a]

Origin	Public Gross	Public Net	Private Gross	Private Net
	Cubic feet per acre			
Dead	2,223	1,072	2,476	1,205
Breakage	850	728	1,522	1,291
Bucked out	66	64	529	491
Lost log	109	105	177	166
Chunk and splinter	255	161	175	134
Top	154	151	146	146
Whole tree	155	151	179	177
Total	3,811	2,431	5,206	3,610

[a] Does not include residue in large piles.

These data are also useful in projecting timber inventories. Material that was dead or cull before harvest has been accounted for by mortality and defect figures in the inventory data base. Thus, only the portion of residue from live trees needs to be deducted to complete calculations of inventory drain.

Special relations-Tables 4 and 5 provide additional data for evaluating the tech-nical and economic feasibility of recovering logging residue in southeast Alaska. These tables show the origin of residue materials and the percentage of volume n large piles. Information on the origin of residue (table 4) helps identify the source of each piece. This does not assume a direct cause-and-effect link between the source and amount of residue, but shows the opportunity for additional utilization should markets or technology change. An example of this is breakage, which frequently occurs as trees fall. Because of loss of product value caused by the break, the damaged section is frequently bucked out. An increase in market value (for pulp or energy, for example) might result in the broken piece being removed as part of the larger log. Similar opportunities, driven by increased product values, may be possible with residue from other origins. In general, material is removed when the demand -and thus the value-is high enough to justify its removal. The totals in table 4 do not equal those in previous tables because of the exclusion of residue in large piles. Collecting reliable information on origin from pieces in large piles was impossible.

The data in table 5 give the percentage that the volume in large piles contributes to total stratum averages, such as those shown in tables 1-3. Large piles usually occur at the landing, thus this volume may be the most economical to recover because yarding costs have already been paid. The average percentage shown above is not very large and does not differ much between public and private ownerships. The concentration of residue in some piles was rather high, as indicated by the percent-ages shown for the highest observed values for each stratum. The highest percent-ages of residue in piles is not correlated with the average volume for the respective

Table 5—Volume of residue in large piles as a percentage of average gross and net volume (wood only), by stratum

Stratum	Gross volume		Net volume	
	Average	Highest	Average	Highest
	Percent			
Public	5	21	4	18
Private	3	27	2	21

stratum; for example, the highest percentage of pile volume may have occurred on the smallest clearcut and therefore would not have been an exceptionally large pile in terms of cubic feet of residue. The importance of these figures is not that they represent a particular volume at the stratum level, but that pile volumes are quite variable and thus represent different recovery opportunities. Where, why, and how the volume in piles differs are important questions to be addressed in feasibility studies and emphasize the need to determine timber sale policies of the land owners when residue assessments are made for a particular area.

Residue Characteristics

Tables 6 through 8 represent residue that is scattered throughout the areas sampled (transect volume) and do not include residue in large piles. Table 9 addresses the distribution of all residue including that in piles. Tables in the appendix provide data by large-end diameter classes for indicating whether the material was live at time of harvest and for other information similar to that in tables 6-8.

Volume by diameter and length classes Table 6 gives the distribution of gross and net residue volume (wood only) for each stratum. Gross volume represents the material that must be handled, whether for product recovery or treatment, and net volume represents the chippable content of residue.

The relation between gross and net volume is important in evaluating which residue materials may be feasibly recovered or removed during initial harvesting. Degree of chippability (that is, soundness) varies considerably with diameter and to a lesser degree with length. This can be demonstrated by comparing the gross and net figures for public lands. For the smallest diameter class (3.1-3.9 inches), total net volume is 98 percent of total gross volume. This percentage declines to a low of 35 percent for the 28.0 + diameter class, which is not totally unexpected. Smaller trees are generally more sound and are left primarily because of their size. Larger residue, from larger trees, is most often left because of defect, not size. The implication of this is that larger pieces, although having higher per-piece volume, have lower recovery ratios and, therefore, increased costs per unit of final product.

Table 6—Gross and net volume (wood only) of logging residue, by small-end diameter and length classes, by stratum[a]

Stratum	Small-end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Cubic feet per acre*						
Public:								
Gross	3.1-3.9	24	32	24	93	121	30	327
	4.0-4.9	12	21	25	75	64	13	213
	5.0-5.9	7	10	12	27	18	5	81
	6.0-6.9	19	22	23	87	61	6	220
	7.0-7.9	3	8	7	33	14	0	68
	8.0-11.9	21	54	43	242	164	21	547
	12.0-15.9	20	50	62	249	191	42	616
	16.0-19.9	5	29	67	136	176	48	463
	20.0-27.9	5	29	39	297	337	146	856
	28.0+	30	15	0	119	208	43	416
Total		150	274	306	1,363	1,359	358	3,810
Net	3.1-3.9	22	29	23	93	121	30	321
	4.0-4.9	8	18	20	69	57	13	188
	5.0-5.9	5	9	11	24	17	5	73
	6.0-6.9	13	17	15	71	57	6	182
	7.0-7.9	1	7	6	29	13	0	58
	8.0-11.9	16	30	34	188	128	16	414
	12.0-15.9	11	25	33	165	110	25	372
	16.0-19.9	2	12	31	70	110	33	261
	20.0-27.9	1	15	25	102	157	110	414
	28.0+	30	3	0	35	65	9	144
Total		114	169	202	851	839	252	2,430
Private:								
Gross	3.1-3.9	20	24	28	63	99	93	330
	4.0-4.9	13	23	11	55	69	46	219
	5.0-5.9	7	9	4	14	21	8	65
	6.0-6.9	15	11	16	61	102	16	223
	7.0-7.9	1	2	6	30	27	14	82
	8.0-11.9	31	23	40	252	220	100	668
	12.0-15.9	18	29	23	144	251	130	598
	16.0-19.9	19	44	41	141	291	86	623
	20.0-27.9	4	67	50	206	455	191	974
	28.0+	89	78	42	350	462	396	1,419
Total		221	313	265	1,319	2,001	1,084	5,205
Net	3.1-3.9	17	21	26	60	97	91	314
	4.0-4.9	8	13	7	42	64	44	180
	5.0-5.9	3	6	3	11	20	8	51
	6.0-6.9	10	8	10	48	90	15	183
	7.0-7.9	1	1	5	27	25	12	73
	8.0-11.9	13	10	22	169	198	82	497
	12.0-15.9	10	9	14	110	174	117	435
	16.0-19.9	18	23	21	103	159	44	370
	20.0-27.9	3	38	32	121	211	128	535
	28.0+	78	69	27	254	261	276	967
Total		164	202	171	948	1,302	821	3,610

[a] Does not include residue in large piles.

Although larger and more detective residue materials may have lower recovery value. they represent the portion of the total volume with the c, higher; values for other re considerations. In particular, large defective logs have potentially significant value for wildlife habitat and nutrient cycling. These other resource values may play an important role in how much and what pieces are removed from the area for conversion to wood products.

Table 12 (appendix) provides diameter- and length-class distribution for the portion of residue that was live at the time of harvest. This information may be significant for utilization options that are different for green versus dead materials. Tables 13 arid 14 provide the same classifications of residue for large-end diameter classes, for ail residue and live only.

Percentage chippable-The suitability of logging residue for a given product usually depends on physical characteristics of the material. A key factor is the nature and extent of defect acceptable for a particular product. Some defects, such as checking and splitting, make wood less suitable for sawn products but have little effect on the quality of pulp chips. Likewise, decay beyond the very early stages may prohibit use for pulp but has much less effect on energy values. For this study, soundness is based on the extent to which residue material is physically chippable, with no reference to a particular product.

Acceptable levels of defect must be defined when assessments of the economic feasibility of recovering residue are made. Material not meeting this standard will be rejected for having too little usable content to justify the costs of handling. The data in table 7 can be used to help make these determinations on a broad scale. Gross and net volumes are given for seven classes of chippability and for live and dead or cull .residue. As noted earlier, live residue is usually more sound than residue from dead or cull trees. This is demonstrated by comparing the total figures by owner. The net volume of live residue for both owners is about 87 percent of gross volume. For dead or cull residue, the net volume is only 48 percent of gross. Similarly, the proportion of volume in the lower chippability classes is higher for dead or cull than for live residue.

The following is an example of the use of the data in table 7. For the public stratum gross volume of dead or cull residue in the 41- to 60-percent-chippable class is 257 cubic feet per acre. Net volume for this class is 129 cubic feet per acre, or about 50 percent of gross. Thus, to recover 129 cubic feet of chippable wood fiber, a total of 257 cubic feet would have to be handled. Net volume identified above is not synonymous with recovery of solid products because defects such as cracks, slits, and incipient decay may reduce the feasibility of use for these products.

Table 7—Gross and net volume (wood only) of logging residue, by live and dead and cull, by percent of chippable material, by stratum[a]

Stratum and volume	Chippable material (percent)							
	0	1-20	21-40	41-60	61-80	81-99	100	Total
	Cubic feet per acre							
Public:								
Live—								
Gross	0	37	67	130	158	367	830	1,588
Net	0	4	20	65	110	330	830	1,359
Dead/cull—								
Gross	195	532	331	257	270	365	274	2,223
Net	0	53	99	129	189	328	274	1,072
Private:								
Live—								
Gross	3	17	113	222	214	517	1,644	2,729
Net	0	2	34	111	150	465	1,644	2,405
Dead/cull—								
Gross	357	439	295	351	324	401	308	2,476
Net	0	44	88	176	227	361	308	1,205

[a] Does not include residue in large piles.

Number of pieces per acre -The ability to economically recover residue hinges greatly on the costs of handling the material. For a given volume, harvesting many small pieces usually costs more than harvesting fewer large pieces. Equipment also differs in ability and efficiency of handling pieces of various sizes. Thus, the number of pieces of residue per acre by size class is an element in decisions on use. Table 8 provides the number of pieces of residue per acre for the same diameter and length classes displayed in previous tables for volume per acre. Similar information is given for live residue in table 15 and in tables 16 and 17, which give the same breakdowns for large-end diameter classes.

Because the data in table 8 are averages for each stratum, the tabulations show fractions of pieces, which do not occur in the real world. Likewise, some diameter or length classes may be represented on one cutover area and not another. This is particularly true for the larger size classes. What is important for most analyses, however, is whether few or many pieces are of a given size class.

An important consideration in economic evaluations of the cost of handling residue is volume per piece. Larger pieces require less handling, yarding, loading, and hauling to meet total product goals. Information on volume per piece can be obtained by using data from tables 6 and 8 of this report, where the volume per acre of a specific. size class is divided by the number of pieces in that class. Table 6, for example, shows for public lands a gross volume of 242 cubic feet per acre in pieces 8.0 to 11.9 inches in diameter and 8.0 to 15.9 feet in length. For the same size class, table 8 shows 35.4 pieces per acre. The average gross volume per piece for this size class is therefore about 6.8 cubic feet. Net volume per piece can be obtained by using data from the same two tables. Tables 13 and 16 can be used to derive similar values for large-end diameter classes.

Table 8—Number of pieces of logging residue per acre, by small-end diameter and length classes, by stratum[a]

Stratum	Small-end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Number of pieces per acre*						
Public	3.1-3.9	18.5	29.6	21.8	68.8	54.5	8.2	201.4
	4.0-4.9	11.1	15.7	13.6	35.5	19.6	2.0	97.6
	5.0-5.9	3.3	4.7	5.6	10.0	4.9	1.3	29.8
	6.0-6.9	6.4	8.8	6.7	22.6	15.4	1.1	61.1
	7.0-7.9	1.0	2.1	1.8	7.5	2.8	0	15.2
	8.0-11.9	3.9	8.2	6.4	35.4	18.2	2.6	74.7
	12.0-15.9	1.8	3.9	5.2	17.2	11.8	1.6	41.6
	16.0-19.9	.3	1.5	3.1	5.9	7.5	1.6	20.0
	20.0-27.9	.2	.7	1.3	8.7	8.8	2.3	21.9
	28.0+	.5	.3	0	2.0	2.9	.7	6.4
Total		47.0	75.6	65.5	213.5	146.5	21.4	569.6
Private	3.1-3.9	19.0	23.8	25.8	46.1	41.4	23.0	179.1
	4.0-4.9	12.2	15.1	7.3	21.5	17.5	8.5	82.1
	5.0-5.9	3.2	4.3	1.8	5.8	5.2	1.8	22.1
	6.0-6.9	5.2	4.0	5.0	15.1	18.6	3.5	51.4
	7.0-7.9	.5	.7	1.5	5.7	4.7	1.8	14.8
	8.0-11.9	5.8	4.2	6.7	31.0	27.1	8.5	83.2
	12.0-15.9	2.0	2.5	2.0	11.5	15.0	4.5	37.4
	16.0-19.9	.8	2.5	2.2	6.3	11.7	3.3	26.8
	20.0-27.9	.2	1.8	1.5	5.8	10.5	4.0	23.8
	28.0+	1.2	1.0	.3	4.2	6.2	3.7	16.5
Total		49.9	59.9	54.1	153.0	157.8	62.6	537.3

[a] Does not include residue in large piles.

As shown in table 8, by far the most pieces per acre are found in smaller diameter classes. This is not true for volume per acre, where larger pieces dominate. This is easily seen by comparing data in tables 6 and 8. For private lands only (table 8), the number of pieces per acre that are less than 8 inches in diameter account for about 65 percent of the total pieces. In terms of net volume per acre (table 6), the same pieces constitute about 22 percent of the average net volume. This does not imply that only larger pieces may be economical to recover; rather, these factors relative to available equipment are important aspects of feasibility studies.

Residue distribution-Equipment used in a logging residue recovery effort may have limitations in ability to reach residue under all terrain conditions. Two factors affecting the type of equipment used to retrieve residue are slope and yarding distance. The degree of slope of the harvested area determines whether groundbased or cable systems are required to yard the residue. Yarding distance affects the size of the system, a major factor in the cost of doing the job. As a rule, relogging does not allow for the cost of new road construction; thus, roads built during the initial logging will generally be used for residue recovery operations. The distribution of residue over harvested areas is therefore important for decisions about equipment needed to gather these materials.

Table 9—Distribution of logging residue by slope and distance to road classes, by stratum[a]

Stratum	Slope	Distance to road (feet) 0-500	501-1,000	1,000+	Total
		Percent			
Public	0-35	59.6	10.5	0.1	70.2
	36+	21.1	8.4	.3	29.9
Total		80.7	18.9	.4	100.0
Private	0-35	50.0	12.5	2.5	65.0
	36+	17.2	13.2	4.6	35.0
Total		67.2	25.7	7.1	100.0

[a] Includes residue in large piles that were usually, but not always, next to a road.

Table 9 gives the average distribution of logging residue on cutover areas by slope and distance to the nearest road. This table includes residue in large piles, which are usually near roads.

Application of Results

Information provided in this report has a wide variety of uses in assessments of logging residue in southeast Alaska. A major use is to determine residue volume that might be available for use at a particular conversion facility. This application requires an estimate of residue expected from harvesting within a supply zone unique to the facility. The following is a **hypothetical example** of how the data in this report can be used to generate an estimate of residue volume for a specific location.

For this example, an estimate of available residue volume is needed for a feasibility study of a proposed wood products facility with a cogeneration operation located in Ketchikan (fig. 8). The area represented in figure 8 is assumed to be the supply zone for the facility. The zone is not precise, in that residue from some areas within the zone may not be available to the facility and bringing some from areas outside the zone may be more cost effective. No attempt is made in this example to account for these deviations. Both wood and bark are needed as input to the processing and energy production operations. Because of the nature of the products being evaluated, only green (live) wood can be used in the manufacturing process.

Two types of data are needed to estimate the volume of residue from the supply zone: (1) annual timber harvest volume or acres for each stratum within the supply zone, and (2) information on residue factors and characteristics for the corresponding stratum. Timber harvest volumes must be obtained from available records of harvest or plans of the timber owners. Residue information needed for the assessment is

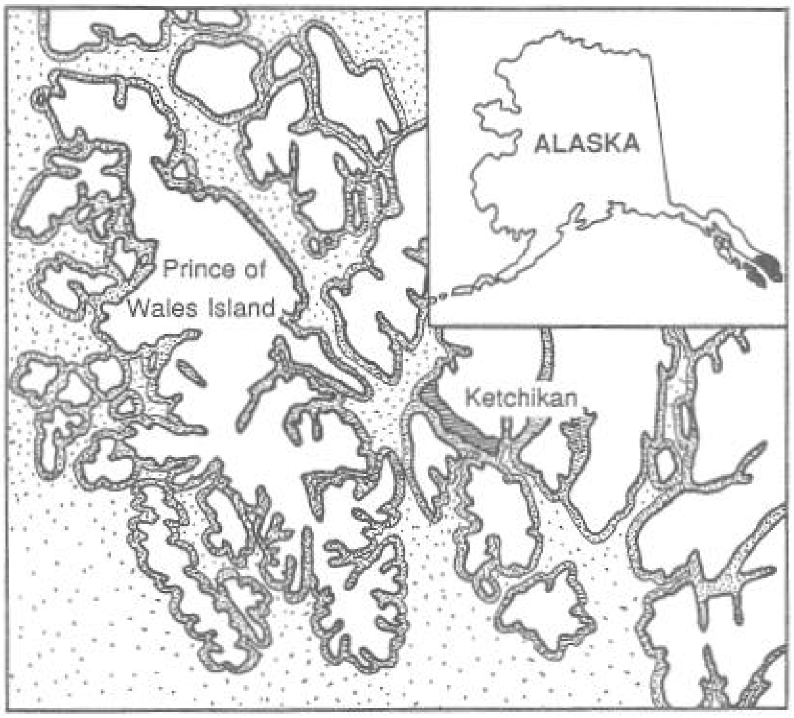


Figure 8—General supply zone for a hypothetical wood-using facility at Ketchikan, Alaska.

taken from this report. The first task is to estimate the total volume of residue generated annually from the supply zone. For this estimate, the ratio of net residue volume is taken from table 1 and the live proportion of net volume from table 3. The tabulation shows the harvest volume and residue ratios used for this example:

Stratum	Estimated annual harvest volume	Residue ratio	Live residue proportion
	(MBF)	(CF/MBF)	(percent)
Public	190,000	79	57
Private	160,000	109	67

Annual residue volume (wood) for the example can be estimated by using the figures shown above:

Public	190,000 x 79 x 0.57 =	8,555,700 cubic feet
Private	160,000 x 109 x 0.67 =	11,684,800 cubic feet
Total		20,240,500 cubic feet

The 20 million cubic feet of residue represents an estimate of the volume generated annually within the supply zone. Because of other considerations, this amount may not be available to the proposed facility; handling costs and equipment limitations, for example, might affect the minimum-size piece that could realistically be recovered. For the situation being analyzed, available equipment was assumed to be able to handle only residue materials at least 6 inches in diameter and 8 feet long. With information from table 6, the volume of residue that meets this size requirement can be estimated.

For this analysis, only net volume displays of residue are applicable. An estimate of the proportion of residue meeting the size requirement is made by eliminating the volume of residue in diameter classes less than 6 inches and length classes less than 8 feet, and dividing the remaining volume by the total volume for the respective display. With this procedure, the proportion of residue meeting the size criteria is computed to be 0.623 for the public stratum and 0.730 for private. Shown below are the calculations for determining the total volume of residue within the supply zone that meets the size requirement:

Public	8,555,700 x 0.623	=	5,330,201 cubic feet
Private	11,684,800 x 0.730	=	8,529,904 cubic feet
Total			13,860,105 cubic feet

Again, this estimate of nearly 14 million cubic feet may not represent the volume of residue available to the facility. Other factors may further limit the availability of some of the material. Here, for example, the equipment to be used in the recovery operation cannot reach beyond 500 feet from a road; residue beyond that distance technically would be out of reach. The data in table 9 can be used to evaluate the impact of this limitation, thereby producing a better estimate of supply for the proposed facility. These data show the proportion of residue within 500 feet of a road to be 0.807 for public and 0.672 for private. The following calculations give the new estimate of total volume of wood residue:

Public	5,330,201 x 0.807	=	4,301,472 cubic feet
Private	8,529,904 x 0.672	=	5,732,095 cubic feet
Total			10,033,567 cubic feet

Assuming no other factors exist that limit the availability of residue to the proposed facility, 10 million cubic feet is the estimate of the annual volume of wood from the supply zone previously defined. As noted in the description of this hypothetical facility, bark will also be used as fuel for the cogeneration operation. The calculations thus far have determined the volume of wood potentially available to the facility. An estimate of the amount of bark is also needed. Bark is assumed to be attached to the residue pieces delivered to the mill. In reality, some of the bark is knocked off the pieces during handling and transport. Because only live residue is being recovered, the loss of bark is not as great as it would be if dead residue was brought to the facility. The computed volume of bark should therefore be considered as a generous estimate. Observations during actual operation would provide a better estimate of the relation between wood and bark volumes.

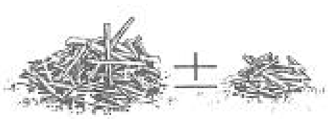
The following process is used to compute the volume of bark associated with the 10 million cubic feet of wood available to the facility (information is from table 1). The proportion of bark relative to wood is derived by subtracting the wood and bark ratio from the wood-only ratio, then dividing by the wood-only ratio. For this example, the proportion for the public stratum is (97-79)/79 = 0.228. The private stratum figure is computed similarly as 0.220. The application of these proportions to the estimate of wood volume by stratum yields the volume of bark expected to be delivered to the facility. This volume is calculated as follows:

Public	4,301,472 x 0.228	=	980,736 cubic feet
Private	5,732,095 x 0.220	=	1,261,061 cubic feet
Total			2,241,797 cubic feet

Given the criteria affecting the availability of residue for the proposed facility, an estimated 10 million cubic feet of wood plus 2.2 million cubic feet of bark can be considered as potential input to the processing and cogeneration operations. These volumes can be converted to weight by using wood (see appendix) and bark density values. For this example, the weighted average density of wood is estimated to be about 24 pounds (dry) per cubic foot. The comparable bark value is about 32 pounds (dry) per cubic foot. Based on these figures, the total wood and bark volumes shown above convert to about 120,000 and 36,000 bone dry tons, respectively.

These estimates of wood and bark would be evaluated relative to the raw material needs of the hypothetical facility. Other factors, such as future harvest levels, changing export markets, competition for the residue; land management objectives, and cost considerations are important in determining the amount of residue available from a supply area. The analyst is responsible for these determinations. Estimates using data in this report provide a good baseline for feasibility studies, such as described in the hypothetical situation above.

Precision of Results



The data in this report represent a significant expansion of information on logging residue in southeast Alaska. The ability to make site-specific analyses of residue availability are greatly enhanced by these data, though not without limitations, however. Table 10 gives relevant statistical information for determining precision of study results. Be aware that errors associated with estimates of components of mean residue (the volume in a specific diameter and length class, for example) are greater than for the mean.

Table 10—Statistical information for determination of sampling precision, by stratum

Stratum	Number of samples	Average gross volume (wood)	Standard error of the mean
		- - - Cubic feet per acre - - - - -	
Public	29	4,011	242
Private	28	5,377	172

Table 11—Range of study data for stand age, harvest volume, area cut, and average residue volume, by stratum

	Sample characteristics			
Stratum	Stand age	Harvest volume	Area cut	Net wood residue volume
	years	mbf/acre	acres	cf/acre
Public	200-450	13-70	17-142	1,328-3,803
Private	200-500	21-49	11-100	2,304-5,248

Table 11 provides information on the range of study data for selected characteristics. This information is included to provide additional insight for applying study results. It may also be useful if application of these data are needed for areas beyond the scope of this report; for example, for an analysis including an area outside the geographic boundaries of this study. If this report is the only available data source, information in table 11 may help determine usefulness of the data. Application should be restricted, however, to the range of data indicated above. The level of accuracy associated with the results of this report does not apply to extensions beyond the scope of the study.

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Metric Equivalents

1inch = 2.54 centimeters
1 foot = 30.48 centimeters
1mile = 1.609 kilometers
1 acre = 0.405 hectare
1 cubic foot = 0.0283 cubic meter
1pound = 0.454 kilogram
1 ton = 0.907 metric ton
1British thermal unit (Btu) = 1,055.87 joules

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Appendix

Conversion factors

Species	Density, dry weight[1]	Higher heating values, dry weight[2]
	(Pounds per cubic foot)	Btu per pound)
Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.)	26	8,260
Spruces (*Picea* spp.)	22	—[3]
True firs (*Abies* spp.)	23	—
Alaska-cedar (*Chamaecyparis nootkatensis* (D.Don) Spach	26	—
Western redcedar (*Thuja plicata* Donn ex D.Don)	19	9,700
Lodgepole pine (*Pinus contorta* Dougl. ex Loud.)	24	8,730
Red alder (*Alnus rubra* Bong.)	23	8,000
Black cottonwood (*Populus trichocarpa* Torr. & Gray)	19	8,510

[1] USDA Forest Products Laboratory (1987).
[2] Arola (1977) and Bergvall and others (1978).
[3] — = no information available.

Table 12—Gross and net volume (wood only) of live logging residue, by small-end diameter and length classes, by stratum[a]

Stratum	Small-end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Cubic feet per acre*						
Public:								
Gross	3.1-3.9	7	6	8	73	118	30	244
	4.0-4.9	4	7	9	47	47	8	124
	5.0-5.9	3	5	7	17	14	4	51
	6.0-6.9	12	8	11	48	35	3	119
	7.0-7.9	0	7	5	21	15	0	49
	8.0-11.9	17	19	30	139	56	8	271
	12.0-15.9	9	16	17	153	34	5	237
	16.0-19.9	0	19	33	50	61	0	165
	20.0-27.9	6	16	23	38	90	80	256
	28.0+	10	0	0	14	41	0	65
Total		72	105	147	606	515	140	1,587
Net	3.1-3.9	7	6	7	71	114	29	237
	4.0-4.9	4	6	8	45	43	7	116
	5.0-5.9	3	4	7	17	13	4	50
	6.0-6.9	9	7	8	44	34	3	108
	7.0-7.9	0	6	4	20	14	0	45
	8.0-11.9	15	15	27	125	51	6	243
	12.0-15.9	7	16	15	113	29	5	187
	16.0-19.9	0	12	28	44	43	0	130
	20.0-27.9	1	14	19	25	69	69	201
	28.0+	10	0	0	14	12	0	37
Total		58	92	129	524	427	126	1,358
Private:								
Gross	3.1-3.9	1	3	8	40	96	91	241
	4.0-4.9	2	5	2	23	56	44	135
	5.0-5.9	1	0	0	6	18	7	35
	6.0-6.9	8	7	7	38	77	14	154
	7.0-7.9	0	1	5	25	21	7	61
	8.0-11.9	11	8	16	119	163	72	392
	12.0-15.9	8	8	11	71	130	93	324
	16.0-19.9	19	25	26	71	126	18	287
	20.0-27.9	4	46	30	89	98	79	348
	28.0+	89	54	28	250	157	167	748
Total		146	161	137	736	947	599	2,729
Net	3.1-3.9	0	3	8	40	95	90	238
	4.0-4.9	1	4	2	22	55	43	132
	5.0-5.9	0	0	0	6	17	7	33
	6.0-6.9	7	6	7	37	76	14	150
	7.0-7.9	0	1	5	24	21	7	60
	8.0-11.9	9	7	13	109	158	64	364
	12.0-15.9	8	7	10	70	118	91	306
	16.0-19.9	18	15	22	65	85	17	224
	20.0-27.9	3	38	22	69	78	59	271
	28.0+	79	53	28	209	122	131	623
Total		130	139	121	655	830	528	2,405

[a] Does not include residue in large piles.

Table 13—Gross and net volume (wood only) of logging residue, by large-end diameter and length classes, by stratum[a]

Stratum	Large-end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Cubic feet per acre*						
Public:								
Gross	3.1-3.9	3	1	0	0	0	0	4
	4.0-4.9	20	32	19	30	4	0	106
	5.0-5.9	2	3	4	15	6	0	32
	6.0-6.9	17	33	25	83	34	0	194
	7.0-7.9	3	3	4	18	27	0	58
	8.0-11.9	23	55	51	236	159	30	557
	12.0-15.9	38	39	69	226	186	26	587
	16.0-19.9	5	44	46	190	138	22	446
	20.0-27.9	5	27	83	335	411	53	918
	28.0+	30	31	0	224	391	225	903
Total		150	274	306	1,363	1,359	358	3,810
Net	3.1-3.9	3	0	0	0	0	0	3
	4.0-4.9	16	31	18	30	4	0	101
	5.0-5.9	1	3	4	15	6	0	31
	6.0-6.9	13	27	21	75	34	0	172
	7.0-7.9	3	3	4	16	27	0	54
	8.0-11.9	16	37	42	207	152	29	485
	12.0-15.9	24	18	42	169	156	24	437
	16.0-19.9	2	21	25	119	77	20	267
	20.0-27.9	1	12	42	140	235	27	460
	28.0+	31	12	0	75	145	149	414
Total		114	169	202	851	839	252	2,430
Private:								
Gross	3.1-3.9	3	2	1	0	0	0	7
	4.0-4.9	20	23	18	19	2	0	84
	5.0-5.9	4	6	5	13	3	0	34
	6.0-6.9	17	18	17	46	21	3	124
	7.0-7.9	2	3	2	9	11	0	30
	8.0-11.9	33	30	42	160	208	67	544
	12.0-15.9	23	29	29	207	266	112	667
	16.0-19.9	12	45	42	186	230	56	574
	20.0-27.9	14	68	54	259	408	180	985
	28.0+	89	85	49	416	847	663	2,151
Total		221	313	265	1,319	2,001	1,084	5,205
Net	3.1-3.9	3	1	1	0	0	0	6
	4.0-4.9	16	20	17	18	2	0	74
	5.0-5.9	2	4	5	13	3	0	30
	6.0-6.9	8	12	14	42	20	3	103
	7.0-7.9	2	2	1	8	11	0	25
	8.0-11.9	15	14	27	136	197	66	457
	12.0-15.9	11	12	15	155	234	104	534
	16.0-19.9	11	22	22	125	177	48	408
	20.0-27.9	13	37	35	171	221	139	618
	28.0+	78	72	30	277	432	458	1,350
Total		164	202	171	948	1,302	821	3,610

[a] Does not include residue in large piles.

Table 14—Gross and net volume (wood only) of live logging residue, by large-end diameter and length classes, by stratum[a]

Stratum	Large-end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Cubic feet per acre*						
Public:								
Gross	3.1-3.9	0	0	0	0	0	0	0
	4.0-4.9	3	8	5	18	3	0	39
	5.0-5.9	1	1	3	12	6	0	25
	6.0-6.9	9	12	11	60	29	0	123
	7.0-7.9	1	1	1	11	23	0	40
	8.0-11.9	13	24	28	142	132	26	368
	12.0-15.9	26	12	36	137	100	19	331
	16.0-19.9	0	24	18	104	24	13	185
	20.0-27.9	6	12	41	94	118	0	272
	28.0+	10	8	0	23	76	80	199
Total		72	105	147	606	515	140	1,587
Net	3.1-3.9	0	0	0	0	0	0	0
	4.0-4.9	3	7	4	18	3	0	38
	5.0-5.9	1	1	3	12	6	0	25
	6.0-6.9	9	11	10	58	29	0	119
	7.0-7.9	1	1	1	10	23	0	39
	8.0-11.9	10	20	27	131	127	26	343
	12.0-15.9	20	11	29	121	90	17	290
	16.0-19.9	0	20	16	82	20	13	153
	20.0-27.9	1	9	34	64	89	0	199
	28.0+	10	7	0	22	37	69	147
Total		58	92	129	524	427	126	1,358
Private:								
Gross	3.1-3.9	0	0	0	0	0	0	0
	4.0-4.9	1	3	5	9	2	0	23
	5.0-5.9	0	0	2	8	3	0	16
	6.0-6.9	4	6	6	32	19	3	72
	7.0-7.9	1	1	0	6	10	0	20
	8.0-11.9	9	9	21	101	179	62	383
	12.0-15.9	11	11	12	124	200	97	458
	16.0-19.9	12	18	22	74	132	37	299
	20.0-27.9	14	47	31	96	140	87	418
	28.0+	89	61	35	282	258	309	1,036
Total		146	161	137	736	947	599	2,729
Net	3.1-3.9	0	0	0	0	0	0	0
	4.0-4.9	1	3	5	9	2	0	22
	5.0-5.9	0	0	2	8	3	0	16
	6.0-6.9	4	5	6	31	18	3	69
	7.0-7.9	1	1	0	5	10	0	19
	8.0-11.9	9	8	19	99	176	62	375
	12.0-15.9	9	10	10	116	196	94	437
	16.0-19.9	11	14	20	71	119	37	276
	20.0-27.9	13	37	25	88	96	85	346
	28.0+	79	56	31	223	205	244	841
Total		130	139	121	655	830	528	2,405

[a] Does not include residue in large piles.

Table 15—Number of live pieces of residue per acre, by small-end diameter and length classes, by stratum[a]

Stratum	Small-end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Number of pieces per acre*						
Public	3.1-3.9	2.5	6.7	7.2	52.0	52.6	8.1	129.2
	4.0-4.9	4.0	4.9	4.9	24.8	15.7	1.3	55.5
	5.0-5.9	1.6	2.0	3.3	6.3	4.2	1.3	18.6
	6.0-6.9	4.2	3.4	3.3	12.5	9.4	.7	33.4
	7.0-7.9	0	1.8	1.1	4.9	2.9	0	10.7
	8.0-11.9	3.3	3.1	4.5	21.0	7.4	1.1	40.3
	12.0-15.9	.9	1.1	1.6	9.9	2.2	.4	16.1
	16.0-19.9	0	.9	1.6	2.2	2.9	0	7.6
	20.0-27.9	.2	.4	.7	1.1	2.3	1.1	5.8
	28.0+	.2	0	0	.2	.5	0	0.9
Total		16.8	24.2	28.2	134.8	100.1	13.9	318.1
Private	3.1-3.9	1.0	2.9	7.2	29.5	39.8	22.3	102.7
	4.0-4.9	1.7	3.9	2.3	12.4	14.3	8.1	42.6
	5.0-5.9	.5	.3	.3	2.5	4.4	1.7	9.7
	6.0-6.9	2.3	2.9	2.7	10.2	15.9	3.0	37.1
	7.0-7.9	0	.5	1.2	4.7	3.5	1.0	10.9
	8.0-11.9	2.0	1.5	2.9	15.9	20.1	5.9	48.3
	12.0-15.9	.8	.8	1.0	6.0	8.7	2.7	20.1
	16.0-19.9	.8	1.3	1.3	3.2	4.9	.8	12.4
	20.0-27.9	.2	1.3	.8	2.5	2.3	1.5	8.7
	28.0+	1.2	.7	.2	2.9	2.0	1.8	8.7
Total		10.6	16.1	20.0	89.9	115.9	48.8	301.3

[a] Does not include residue in large piles.

Table 16—Number of pieces of residue per acre, by large-end diameter and length classes, by stratum[a]

Stratum	Large-end diameter	Length (feet)						
		1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Number of pieces per acre*						
Public	3.1-3.9	3.1	1.1	0.2	0.5	0	0	4.9
	4.0-4.9	20.5	32.4	19.2	31.1	4.3	0	107.4
	5.0-5.9	2.1	3.8	4.9	15.2	5.9	0	31.9
	6.0-6.9	8.4	16.0	12.9	45.5	20.8	0	103.6
	7.0-7.9	1.6	1.6	2.1	9.8	13.6	.7	29.5
	8.0-11.9	6.4	12.1	12.4	55.5	45.2	8.8	140.5
	12.0-15.9	3.9	4.4	7.4	26.5	24.9	4.1	71.2
	16.0-19.9	.3	2.5	3.3	12.3	9.8	1.8	30.0
	20.0-27.9	.2	1.0	3.1	12.6	15.2	2.1	34.2
	28.0+	.5	.7	0	4.4	6.9	3.9	16.4
Total		47.0	75.6	65.5	213.5	146.5	21.4	569.6
Private	3.1-3.9	3.8	2.2	2.0	0.2	0	0	8.2
	4.0-4.9	20.1	23.5	18.3	20.0	3.0	0	84.9
	5.0-5.9	4.2	5.5	5.5	13.5	3.2	.2	32.0
	6.0-6.9	8.2	9.7	8.8	26.3	12.8	2.2	67.9
	7.0-7.9	1.2	1.8	1.0	4.5	6.0	.3	14.8
	8.0-11.9	7.5	8.0	10.0	37.8	54.4	20.0	137.6
	12.0-15.9	2.7	3.3	3.5	24.3	34.1	17.3	85.2
	16.0-19.9	.7	2.8	2.7	11.8	15.1	5.7	38.8
	20.0-27.9	.5	2.0	1.8	9.2	15.6	7.8	36.9
	28.0+	1.2	1.2	.5	5.5	13.5	9.2	31.0
Total		49.9	59.9	54.1	153.0	157.8	62.6	537.3

[a] Does not include residue in large piles.

Table 17—Number of live pieces of residue per acre, by large-end diameter and length classes, by stratum[a]

Stratum	Large-end diameter	Length (feet) 1.0-3.9	4.0-5.9	6.0-7.9	8.0-15.9	16.0-31.9	32.0+	Total
	Inches	*Number of pieces per acre*						
Public	3.1-3.9	0.2	0.4	0	0.4	0	0	0.9
	4.0-4.9	3.8	8.3	5.4	19.0	3.4	0	39.9
	5.0-5.9	1.3	.9	3.8	12.8	5.8	0	24.6
	6.0-6.9	4.5	5.6	5.4	34.3	18.1	0	68.0
	7.0-7.9	.7	.7	.5	6.5	12.3	0.7	21.5
	8.0-11.9	3.4	5.1	6.3	34.9	38.9	8.0	96.5
	12.0-15.9	2.5	1.4	4.2	16.4	13.9	3.1	41.6
	16.0-19.9	0	1.3	1.1	6.3	2.2	1.1	11.9
	20.0-27.9	.2	.4	1.4	3.8	4.3	0	10.1
	28.0+	.2	.2	0	.4	1.3	1.1	3.1
Total		16.8	24.2	28.2	134.8	100.1	13.9	318.1
Private	3.1-3.9	0	0.2	0	0	0	0	0.2
	4.0-4.9	1.8	3.5	5.5	9.7	2.5	0	23.1
	5.0-5.9	.5	.8	2.0	8.9	3.2	0.2	15.6
	6.0-6.9	2.2	3.0	3.4	18.1	11.7	2.2	40.6
	7.0-7.9	.5	.8	.2	3.0	5.4	.3	10.2
	8.0-11.9	2.0	2.9	4.7	24.8	48.0	18.6	101.0
	12.0-15.9	1.2	1.3	1.5	13.9	26.0	15.1	59.0
	16.0-19.9	.7	1.2	1.3	4.7	9.6	4.0	21.5
	20.0-27.9	.5	1.5	1.0	3.2	5.4	4.0	15.6
	28.0+	1.2	.8	.3	3.5	4.2	4.4	14.4
Total		10.6	16.1	20.0	89.9	115.9	48.8	301.3

[a] Does not include residue in large piles.

Glossary

Available timberland: Forest land producing or capable of producing 20 cubic feet per acre per year of industrial wood under management and not withdrawn or reserved from timber use.

Clearcut: A harvest operation in which all, or nearly all, trees in a stand are cut in one operation.

Cutover area: Synonymous with sample unit or sample area; the area encompassing a single harvest operation (for this study, a clearcut).

Diameter:

- **Intersection**-Diameter of residue pieces measured inside the bark at the point where a piece intersects a line transact.
- **Large-end**-Diameter measured inside bark at the largest end of a piece of residue, to a 3.01-inch minimum, no maximum.
- **Small-end**-Diameter measured inside bark at the smallest end of a piece of residue, to a 3.01-inch minimum.

Harvest volume: Net scaled volume of timber removed, or estimated to be removed, from a cutover area during harvesting; expressed in thousand board feet (log scale, as reported by land owners) per acre (MBF/AC).

Line transect: A vertical sampling plane, with no width, along which all intersecting residue pieces are measured.

Logging residue:

- **General-**All down and dead woody material existing on a cutover area after harvesting is completed; no standing trees or portions thereof were included in the study.
- **Specific-**All logging residue (as defined above) 3.01 inches and larger in diameter inside bark (d.i.b.) and 1.0 foot and longer in length; includes limbs, slabs, and splinters.

MBF: One thousand board feet of logs; a measure of the volume of timber harvested.

Owner class:

Private-Lands owned by private individuals, forest industries, and Native and other corporations.

Public-Lands owned by the public or managed by a public agency.

Residue volume:

Chippability-Condition of residue sound enough to be physically handled and capable of producing usable chips; includes residue exhibiting early stages of wet or dry rot.

Cull-Residue from trees that were cull (less than 25 percent sound) at 'he time of harvest.

Dead-Residue from trees or portions of trees that were dead before harvest; includes material on the ground at the time of harvest.

Gross-Volume of a piece of residue measured only by its external dimensions; includes rot, cracks, and missing parts.

Live-Residue from trees or portions of trees that were alive before they were cut or knocked down during harvest.

Net-The usable portion of a piece of residue; for this report, usability is based on physical chippability of the material and does not imply solid product potential.

Origin:

Breakage-A piece of residue (to a 6-inch minimum) bucked out of a tree because of breakage at one or both ends.

Bucked out-A piece of residue bucked out of a tree and left because of defect or grade deficiencies.

Lost log-A piece of residue, usually bucked at both ends, that is apparently sound and of such size and species that it normally would be removed during harvest.

Slab or splinter-An irregularly shaped piece of residue originating from but not connected to a tree or log; must meet specific definitions of residue, noted above.

Top-Residue from the upper stem portion of a tree; less than 6 inches in diameter for this study.

Whole tree-An entire tree (live at the time of harvest) that was cut or knocked down by equipment during logging but was left intact.

Stratum: A category of timber harvest area defined for this study by land ownership.

Supply zone: A uniquely defined area containing timber, or logging residue in this study, that is considered to be potentially available for a processing facility.

YUM (or PUM): Terms used by the USDA Forest Service for large piles of residue yarded or bulldozed to a common location. If the residue has been piled with some degree of uniformity it is referred to as PUM (piled unmerchantable material); otherwise, the term YUM (yarded unmerchantable material) is used.

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