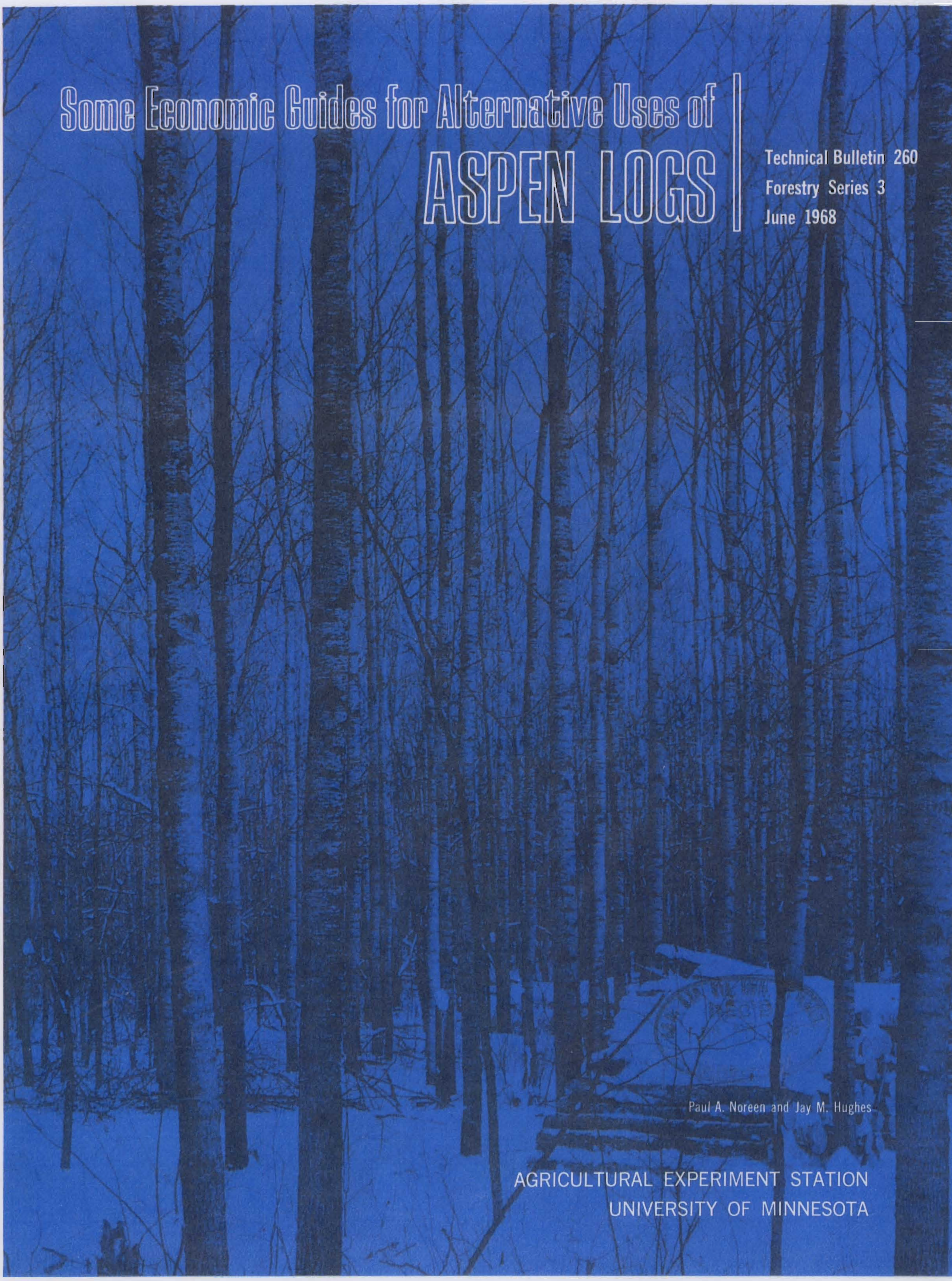
Some Economic Guides for Alternative Uses of ASPEN LOGS

Technical Bulletin 260
Forestry Series 3
June 1968



Paul A. Noreen and Jay M. Hughes

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

Table of Contents

Acknowledgments

Support for this study was provided by the Minnesota Agricultural Experiment Station and the Boise Cascade Corporation. The authors especially wish to thank Messr's. F. T. Frederickson, J. W. Hubbard, and T. V. Hellings of Boise Cascade for providing invaluable assistance during the progress of the study and the writing of this report.

We also wish to thank the owners and managers of the many sawmills and plywood mills in Minnesota, Wisconsin, and Canada who supplied much of the information needed for this study.

Cover photo courtesy U.S. Forest Service.

List of Tables

List of Figures

Paul A. Noreen and Jay M. Hughes*

Study in Brief

Aspen a Vast Reservoir of Wood and Fiber

All available data point to vast amounts of aspen timber available for use. Whether this potential for greatly expanded production will ever be realized depends largely upon developing new markets.

A Variety of Product Possibilities

Aspen has long yielded many products from firewood, fence posts, and pulp to boards, boxes, and veneer. Veneer seems especially promising as plywood markets expand.

Conversion Return Analysis Provides Benchmarks for Best Economic Utilization

One way to measure the economic opportunity for expanded aspen utilization is to estimate its relative profitability in alternative uses. Conversion return analysis enables buyers and sellers to make the best economic use of aspen logs.

Pulpwood Generally a Low-Valued Use of Aspen when Other Markets Exist

Apparently when good markets for aspen lumber and plywood exist, pulpwood is a relatively low valued product, especially from the larger logs. In any event, conversion return analysis helps determine which alternative use will yield the greatest profit to buyers and sellers of aspen logs.

Aspen Highlights

Aspen (*Populus tremuloides and Populus grandidentata*) trees and stands are familiar components of the forested landscape in Minnesota and the northern half of the United States and Canada. The gold fall foliage of aspen is the subject of prize winning photographs. Its shoots and bark are staples in the diets of wildlife. It provides shelter for domestic livestock and a pleasant backdrop for picnickers. It is also a resource with commercial capabilities for the manufacture of a variety of wood products. This study is concerned with the allocation of aspen logs among these commercial product alternatives.

Aspen Resource

Consolidated data for the nation's aspen resources are not readily available. However, of the 508.8 million acres of commercial forest land in the United States, about 8 percent are classified as aspen and related species forest types.[13] These forest types, as well as others with minor amounts of aspen, contain over 16 billion cubic feet of aspen and cottonwood. Nearly half of this amount is concentrated in the Lake States.

The aspen resource is particularly prominent in Minnesota where nearly a third of the commercial forest land area, 5.4 million acres, is in the aspen forest type.[9] Moreover, the 3.0 billion cubic feet of aspen growing stock is nearly a third of the growing stock volume in all of Minnesota's forests.

Product Capabilities of Aspen

A variety of products can be manufactured from aspen. It is of increasing importance for pulp manufacture. Its ease of workability makes it desirable for various lumber products. It is readily made into veneer. Its light color, light weight and relative freedom from taste and odor make aspen desirable as a packaging material. Excelsior has long been manufactured from aspen. In short, where great strength is not desired in the end product aspen has a very wide range of use possibilities.

Development Possibilities

The Minnesota situation is representative of the Cinderella role which may be played by aspen. Originally considered a "weed tree," aspen has now become an important raw material for Minnesota's woodusing industries. In 1966 aspen accounted for 53 percent (612 thousand cords) of the total pulpwood harvest.[1] In 1965 it amounted to 25 percent (25 million board feet) of the total lumber production in Minnesota.[6] Although aspen makes up an increasingly large portion of the state's industrial roundwood consumption, the actual cut in 1960 was less than one-third of the desired cut. Even when considering only the material of sawlog size, the actual cut is slightly less than one-half the desired cut.[8] The result of these relatively low cutting levels is a growing reserve of aspen timber. Minnesota, therefore, appears to have a sufficient aspen resource to support additional industry.

Veneer and plywood manufacture offer interesting prospects for aspen. The production and marketing of aspen plywood by Canadian firms has aroused interest in Minnesota and other states where aspen is abundant. The market position for aspen veneer and plywood will likely be strengthened by the following trends: (a) increasing number of families causing increased housing demand, (b) increasing demand for second homes, (c) decreasing supply of "fine"* hardwood veneer timber, (d) increasing prices of Douglas fir veneer logs, and (e) increasing competition for stumpage in the Southern States. However, before this use of aspen can be considered seriously, the plywood profitability must be compared with the profitabilities of other uses. This study helps to answer this question.

Conversion Return Analysis

Log buyers and log sellers need to know how much the logs they buy or sell are "worth." The worth or value of logs, especially to the buyer, varies according to the costs of processing them into subsequent products, the price of these products, and the amount of saleable products obtained from the logs. This value or worth may or may not be closely related to prices paid for the logs. Log price paid will depend on the willingness of

* Research assistant and associate professor, School of Forestry, respectively.

* "Fine" hardwoods are the higher valued hardwood species which have traditionally been used in veneer manufacture, e.g., black walnut, red and white oak, birch, maple, etc.

both the buyer and seller to buy and sell, as well as precise levels of costs.

What is Conversion Return?

Two related measures of worth or value of a log are "conversion surplus" and "conversion return." These have become traditional value measurements in forestry and have been differentiated by Duerr.[3] Figure 1 provides a useful guide to the general relationships involved.

Figure 1 shows that conversion surplus is the larger of the two concepts. It is derived by subtracting total variable costs from total revenue. At output level X, total conversion surplus would equal $350 minus $150, or $200. Variable costs in Figure 1 are those costs which change, in total, as output level changes. These costs are associated with numerous inputs such as labor, power, and fuel; transportation; materials and supplies incorporated in or directly used in the manufacture of the product; and selling. The important characteristic is, however, that these costs *in total* must increase or decrease as the amount of production changes. In a sense these are the directly-associated costs which must be incurred in order to turn a wheel or produce and sell anything. Plant and equipment may exist; but without labor and materials no product is produced.

Conversion surplus is thus a residual from which a log buyer pays for such items as his own labor or management (profit) and for services rendered by government (taxes) and by lenders (loan repayments). This surplus must also pay any other expenses which do *not* vary, in total, as a result of changes in output. These costs are therefore called "fixed" and are incurred whether or not any production occurs. These can include depreciation, insurance, rent, and "overhead" to the extent that these, again, do *not* change with changes in output.* We therefore can identify two general components of the conversion surplus package: (1) profit and risk, and (2) fixed costs.

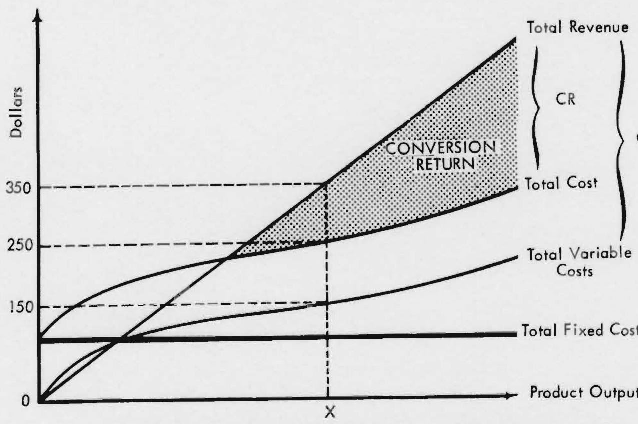


Figure 1. General relationship between conversion return and conversion surplus.

* Economically speaking these are "short run" concepts. In the long run, changes in investment levels eliminate absolute fixed costs. However, the analysis is relevant for most cases which deal with existing plant or "average" short run alternatives.

The terms "profit" and "risk" are subject to some debate in economics and business literature. Generally the term "profit" refers to an accounting difference between sales receipts and costs incurred for all *purchased or hired* factors of production and overhead. It will also exclude depreciation. It thus represents a residual share to be claimed by the owners of a business from which they pay themselves for all services and goods not elsewhere accounted for, and which they have contributed to the business. Accounting profit in this sense can also be thought of as the imputed value of wages, interest, and rent payable to the owners of a business; and in this sense "pure profit" may not exist. The present study adopts the simple residual or accounting profit concept subject to the definitions of cost employed. Profit thus becomes generally analogous to conversion return which is discussed below.

There are elements of uncertainty in any enterprise. Resource availability uncertainties, market uncertainties, political uncertainties all influence the business decisions of enterprise owners (or potential enterprise owners). Owners can reduce the impact of these uncertainties by adding a "safety margin" to estimates of net return or "profit" as a premium for assuming the burden of uncertainty. This "risk premium" is great or small enough, in the judgment of the businessman, to recover losses which may occur. Exactly how this is to be done is a matter of debate also. As a practical matter, the risk margin may be *added to costs,* thus *reducing* estimates of net profit or conversion return. Payment of the risk premium thus is assigned a higher priority call on revenues than is profit. This study assumes such a margin, whether specified separately or not, is accounted for in the estimation of "profit" or conversion return.

Conversion return, simply put, is conversion surplus shorn of fixed costs. It is this amount that log buyers and sellers will most strongly wish to maximize. In Figure 1, conversion return at output level X is $350 minus $250 or $100. Thus, in this example, the amount remaining to pay profits and any non-variable (in the sense above) expenses left after paying fixed costs is $100.*

Both conversion surplus and conversion return can be used for comparative valuation purposes. It can be argued that conversion surplus is a less cumbersome—i.e., simpler—measure for comparison purposes because it does not require estimation of fixed costs and may therefore be preferred. However, since conversion return is the measure which more nearly represents the business-

* Duerr's (3) distinction between "conversion surplus" and "conversion return" is somewhat ambivalent inasmuch as conversion return is stated to be less than conversion surplus by the amount of "fixed costs" (see p. 383); yet it also includes a "profit allowance" which in turn includes interest on borrowed capital. If interest costs do not vary with production levels, they are appropriately considered "fixed." However, interest payments in practice may, like wages and other variable costs, have a first claim on revenues with payments to principal classed as "fixed." For convenience in economic analysis, interest and principal payments are customarily taken together as a fixed cost. This convention is followed in this study.

man's objective and since fixed costs may be no more difficult to estimate than variable costs, the conversion return approach is taken in this study.

Buyer's vs. Seller's Conversion Return for Logs

The conversion return value of logs to a buyer is estimated by subtracting all associated fixed and variable costs as described above from the value of the final products sold from the logs by the buyer. The point of estimate may be the standing tree, the roadside log deck, or the mill yard.

In any case, the conversion return so calculated is not a net "profit" unless the logs are obtained free of charge; for any price paid by the buyer for the logs (assuming the log price has not been included in variable costs) will detract from conversion return. The more the buyer must pay for the logs, the less of the $100 in Figure 1 is retained for profit and risk.

A log seller has a different view of the value of the logs and a more difficult problem estimating conversion return. If no price has been established for logs, the seller has no direct starting point for estimating his conversion return. In such a case, he must assume a reasonable price and gross receipts figure or he must estimate conversion return following the buyer's procedure. By estimating conversion return of the finished logs at the point of delivery to the buyer, the seller has determined a *potential range of gross receipts.* In Figure 1, for example, the potential range of gross receipts is from $0 to $100 at output level X.

To determine a basis for log price negotiation within the potential range of gross receipts, the seller will want to estimate his own fixed and variable costs incurred in making the logs and bringing them to the point of sale to the buyer. The sum of those costs must be subtracted from the estimate of buyer conversion return at the point of delivery. The result, of course, is a total conversion return for the logs which will be divided between the buyer and the seller by negotiation at the point of delivery. If, for example, log making (including stumpage costs as a variable cost) and delivery costs were $70 in the case portrayed in Figure 1, the conversion return (the amount remaining for profit and risk for both buyer and seller) would be $30. Thus, if the log buyer paid $80 for these logs his conversion return would be $20 and the log seller would obtain a $10 conversion return.

In the present study conversion returns are estimated at the point of delivery of logs to the buyer. This is, therefore, a log buyer's conversion return. It also is the potential range of gross receipts for the seller.

A word of caution is needed. The above discussion assumes that estimated conversion return sets the limits for gross receipts and subsequent price negotiation. Whether or not this assumption is valid will depend on the needs and willingness to buy and sell of buyers and sellers. If the seller, for instance, is in a weak bargaining position he may be willing to sell at a price which yields him a zero or negative conversion return. If, in the case above, the seller accepted $70 for his logs, he would realize $0 conversion return. In this case he has lost his estimated profit and risk margin; however, he has recovered all of his fixed and variable costs. Assuming that of his $70 total costs, $50 were variable costs and $20 were fixed costs; it might be economically rational for a short time to accept gross revenue as low as $51. The reason is that as long as the price received will cover variable costs plus at least a token amount of fixed costs, it "pays" to continue to operate—for a short time—hoping that future price increases will make up the deficit. If the seller did not operate at all he would still incur *all* of the fixed costs. His loss would thus be equal to all of fixed cost rather than just a portion of it.

Conversion Return for Individual Logs of Different Diameters

The preceding discussion has outlined the basic ideas of conversion return analysis. The discussion has been in terms of logs as groups; but it also applies and perhaps is more frequently used to evaluate profitability of an individual log or to compare groups of logs whose average sizes differ.

Size of log measured by diameter, with all other quality characteristics held constant, is generally used to separate logs on the basis of value. The larger the log, generally, the greater the value. Larger logs yield more saleable products compared with small logs; and the handling time and cost *per unit of product* is lower with larger logs. Moreover, log diameter is one of the easiest characteristics to identify. For these reasons, log diameter is frequently used to sort logs into value classes and to choose among alternative product possibilities.

Figure 2 shows the expected general relationships of costs and returns when log size is varied. Again, conversion return is measured as the difference between total costs and total revenue. Variable costs are those which in total change as log diameter changes; and fixed costs are those which do not change in total as log size is varied. It is also important to realize that the curves in Figure 2 are generalized and somewhat theoretical. Nevertheless, there are good reasons for expecting these

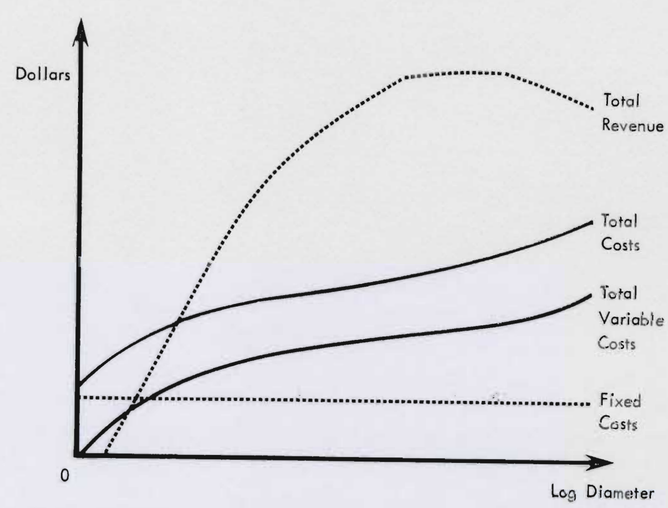


Figure 2. Expected general relationships between log diameter and costs and revenues.

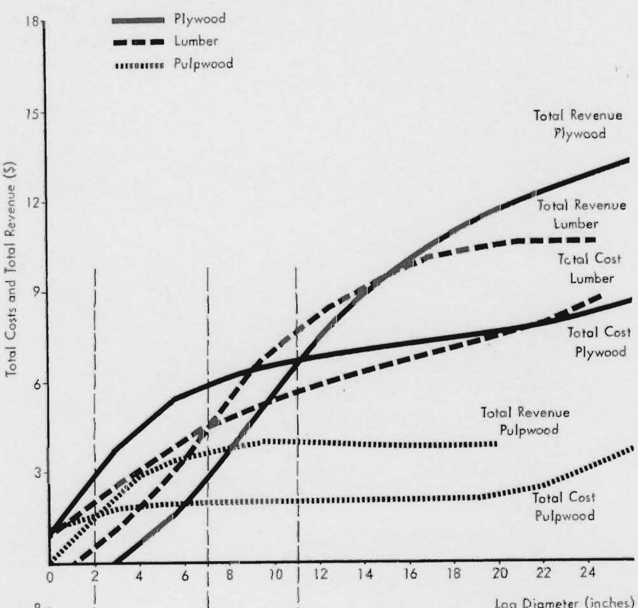
general relationships to hold for any situation in which given kinds and amounts of capital equipment and plant are held constant.

Best Log Utilization

Figure 2 lends itself to several kinds of analyses when diameter of logs is varied. For example, for any given end product such as lumber, the relationships of Figure 2 suggest the most profitable log size; i.e., the diameter at which the difference between total revenue and total cost is greatest. This, in turn, suggests the most profitable size to which trees should be grown and is the general basis for "financial maturity" evaluations in timber production.[4]

Figure 2 relationships may also be used to allocate logs of a given diameter to alternative product possibilities. Each product alternative like lumber, plywood, or pulpwood will have a unique set of curves as in Figure 2. Thus, it is possible to estimate conversion return for any log size for any given product alternative. A rational log buyer (or seller) will tend to allocate any given log (of a given size) to that alternative which yields the greatest conversion return. Figures 3 and 4 depict a generalized comparison of costs, revenues, and resultant conversion returns for a range of log diameters

Figure 3. Total costs and total revenues for a range of log diameters and three product alternatives.



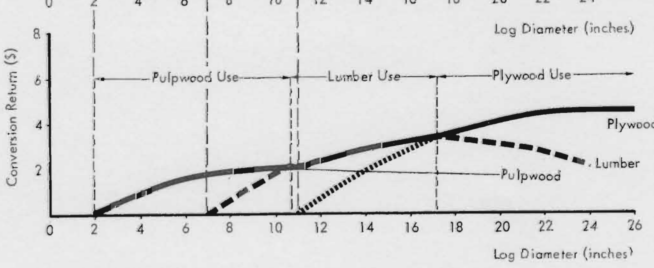


Figure 4. Conversion return for a range of log diameters and three product alternatives.

and three product alternatives. According to Figure 4, in this hypothetical case, logs less than about 11 inches in diameter earn their highest conversion return as pulpwood. From 11 to 17 inches in diameter, lumber is the most profitable use. Plywood is the most profitable use for logs larger than 17 inches in diameter.

The above discussion has illustrated the general idea of conversion return analysis. This method of analysis is employed in the following discussion of the best economic use of aspen logs.

Study Methods

The objective of this study is to determine the conversion return of various aspen log sizes, for the alternative product uses of: (1) plywood, (2) graded lumber, (3) ungraded lumber, and (4) pulpwood. The relative profitability of these various uses can be determined by comparing these conversion returns.

Several data sources are used. Pulpwood log volumes by log size were developed from wood yard data supplied by the Mando Division of the Boise Cascade Corporation. Much of the information used in the development of plywood costs and values was obtained from Canadian plywood mills as compiled by the Canadian Department of Industry.[10] Aspen veneer log yields were obtained from United States Forest Products Laboratory data.[2] A time study of aspen log turning was conducted at an integrated hardwood veneer, plywood, and sawmill to develop costs by log size.

Throughout the study, it is assumed that log lengths are 100 inches and log diameters are measured at the small end of the log. No attempt has been made to distinguish among log grades. Consequently, the analysis may be considered to represent "average" quality aspen logs.

All conversion return calculations in this study are estimated at the point of log delivery to the mill yard.

Pulpwood Logs

Conversion return for aspen logs used for pulp and paper manufacture presumably should begin with the price of paper or pulp f.o.b. the mill and all paper or pulp manufacturing costs. This was impossible in the present study. Consequently, an adjusted mill yard price of rough pulpwood was used. Average current delivered rough pulpwood prices were *increased* by an amount equivalent to estimated risk and "profit" margins required as payment for services performed by the owners of the business. This was necessary to make this conversion return comparable with that calculated for lumber and plywood. In the latter two cases, no estimate of risk and profit margins were available. Thus the conversion return resulting from subtracting costs from revenues includes the profit and risk margin. In the case of unadjusted rough pulpwood prices, it is assumed that the risk and profit margins have been deducted as well as fixed and variable cost.

For the purposes of this study a margin of 9 percent, in accord with Segur's discussion,[8] was used to obtain an adjusted market value for rough pulpwood delivered to the mill of $16.35 per cord.

Using data from a wood yard study conducted by the Mando Division of the Boise Cascade Corp., the cubic foot volumes of various sized aspen logs were determined. These 1,339 logs were 100 inches long and varied from 8 to 16 inches in small-end diameter. They represented a good cross-section of the aspen-producing area of northern Minnesota.

From the same data, cubic foot volume per cord was determined. Since there was no apparent correlation between average diameter per cord and cubic foot volume per cord, an average volume per cord was used. Using the adjusted market value and the average cubic foot volume per cord for aspen pulpwood, a market value per cubic foot was calculated. This figure was in turn multiplied by the cubic foot volume per log to obtain pulpwood value per log by log size (Table 1).

Table 1. Value of aspen pulpwood logs

(1) Diameter	(2) Volume/Stick	(3) Value/Stick[1]
inches	cu. ft.	
8	3.192	$0.66
9	3.915	0.81
10	4.976	1.03
11	5.979	1.24
12	7.188	1.49
13	8.208	1.71
14	9.935	2.07
15	11.036	2.29
16	12.799	2.66

[1] Figures in this column are computed by multiplying column 2 times the market value per cubic foot of $0.208 per cubic foot (78.64 cubic feet per cord).

Table 2. Aspen plywood production costs per thousand square feet

Factor	Listed[1] cost	Cost adjusted to 3/8"	Cost adjusted to U.S. $	Cost[2] adjusted to May 1967
Variable costs per unit output:				
Direct labor	$7.20	$8.64	$7.95	$8.28
Indirect labor	0.85	1.02	0.94	0.98
Fixed costs[3]	7.50	9.00	8.28	8.27
Power	2.00	2.40	2.21	2.22
		Total Variable Cost:		$19.75
Constant costs per unit output:				
Supplies	$1.50	$1.80	$1.66	$1.66
Glue	4.00	4.80	1.42	4.33
		Total Constant Cost:		$5.99

[1] These costs were taken from Sudburg's study (10) and were given on a 5/16-inch basis.

[2] Costs were adjusted for price changes from the time of Sudburg's study to May 1967.

[3] Fixed costs include depreciation, insurance, inventory charges, and rent.

Veneer Logs

Production Costs—Veneer Logs: Because aspen plywood is presently produced in Canada, much of the data used was obtained from Canadian sources. From a survey of several aspen veneer and plywood mills, Sudburg[10] developed average production costs per thousand square feet (5/16-inch basis). These were adjusted to a 3/8-inch basis, and then converted to United States dollars using a conversion ratio of 0.92 United States dollars per Canadian dollar. Finally, the costs were converted to May 1967 dollars using: (1) the all commodities wholesale price index for fixed costs and supplies; (2) the electrical wholesale price index for power; (3) the synthetic resin wholesale price index for glue; and (4) the ratio of May 1967 average veneer and plywood industry wages to the average 1966 veneer and plywood industry labor costs (Table 2).

Costs are grouped into two categories: (1) costs *per unit* output which change as output level is changed and (2) costs *per unit* output which are constant as output level changes. These classes are *not* analogous to variable costs and fixed costs previously discussed. The earlier classification is based on variability or fixity of total costs while the present classification is based on the variability or fixity of *per unit* costs. Therefore, although the fixed costs referred to under "variable" costs in Table 2 are constant in total (i.e., true fixed costs) they do not represent constant per unit costs. Similarly, the "constant" costs referred to in Table 2 are variable in total (i.e., true variable costs) but represent a constant per unit cost. This somewhat confusing classification is necessary to compute production costs in Table 4.

To generate costs by log size, a time study was conducted on a lathe producing aspen veneer. This study was made at a hardwood veneer mill in Wisconsin which used a lathe equipped with retractable chucks and a backup role. Turning time consisted of the period from the beginning of turning to the rejection of the core. Loading time was defined as the period between the rejection of the previous core to the beginning of turning of the present log. Times were recorded to the nearest one-hundredth of a minute on 94 logs ranging from 9 to 16 inches in diameter.

Although loading time proved to increase significantly with log diameter, it is assumed that loading time would be independent of log diameter in an operation equipped with a mechanical lathe charger. Therefore, only turning time was used for calculating purposes.

The following formula was calculated for estimating turning time by log size:

$$Y = 1.2443 - 0.13654X + 0.010.782X^2$$

where:

Y = turning time in minutes, and
X = log diameter in inches (small end).

This equation proved highly significant at the 5 percent level and had an "r" value of 0.726. Figure 5 contains a graphic representation of this equation.

Table 3. Development of hourly production rate for aspen plywood

(1) Diameter	(2) Production[1] time	(3) Adjusted[2] production time	(4) Logs per[3] hour for two lathes	(5) Veneer[4] yield per log	(6) Production[5] per hour (sq. ft.)
	minutes	minutes		sq. ft.	sq. ft.
8	0.925	0.837	143.3	25.0	3,584
9	0.972	0.880	136.4	32.4	4,420
10	1.040	0.941	127.5	41.6	5,304
11	1.130	1.023	117.3	56.1	6,583
12	1.241	1.123	106.8	76.0	8,120
13	1.374	1.243	96.5	95.9	9,254
14	1.529	1.384	86.7	106.8	9,261
15	1.745	1.579	76.0	113.6	8,632
16	1.903	1.722	69.7	118.8	8,277

[1] Taken from Figure 5 plus 0.083 minutes of loading time per log.
[2] Column 2 adjusted to production rate in Sudburg's study, using an adjustment factor of 0.9050.
[3] 60 minutes divided by column 3. This was then doubled to obtain production per hour for two lathes, since the typical mill in Sudburg's study had two lathes.
[4] Taken from Figure 6.
[5] Column 4 times column 5.

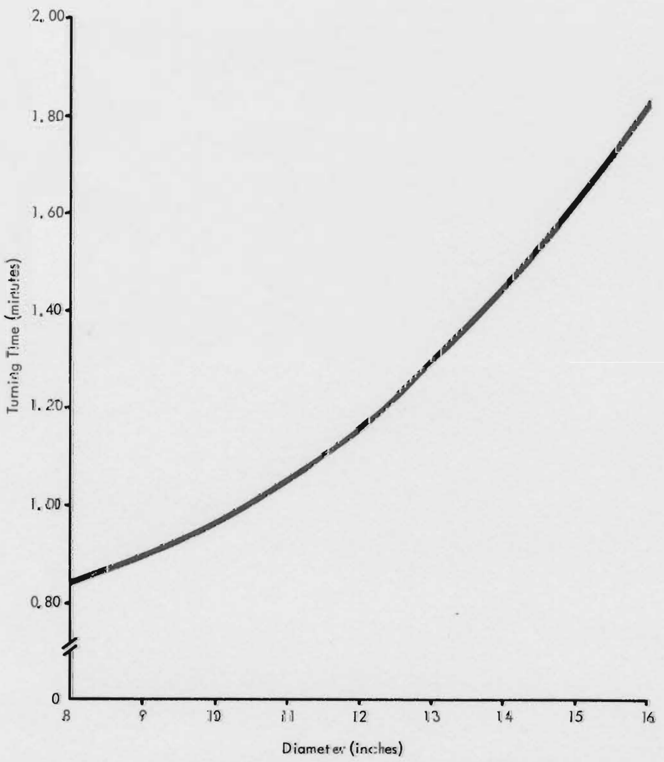


Figure 5. Relationship of lathe turning time to diameter of aspen logs.

Using these turning times, it was possible to convert the average costs from Table 2 to costs by log size.[10] According to Sudburg's study, average production with 12-inch logs was 4,060 square feet (⅜-inch basis) per hour per lathe. By using time for 12-inch logs from Figure 5, plus a loading time of 0.083 minutes per log, and the veneer yield for 12-inch logs from Figure 6, an hourly production rate of 3,674 square feet (⅜-inch basis) was computed.* This computed production rate assumes that the mill is equipped with a mechanical lathe charger.

The ratio of the computed production rate to the production rate of Canadian mills per lathe, was used to adjust the production time of column 2 of Table 3. These adjusted production times were converted to logs processed per hour, using two lathes, and multiplied times the veneer yield per log to obtain production per hour by log size for the typical Canadian mill as described by Sudburg.

The next step was to convert production rates to costs. By multiplying the average variable costs per thousand square feet from Table 2 times the average production rate of Canadian mills (in thousands of square feet per hour), average variable costs per hour are obtained. This figure was then divided by production rates for logs of various sizes (Table 3) to obtain variable costs per thousand square feet, by log size. Total cost per thousand square feet is simply the sum of the calculated variable costs (Table 4) and constant costs (Table 2).

A weighted average gross value of aspen plywood was developed from information from Canadian aspen plywood mills. Total cost per thousand square feet was deducted from the gross value f.o.b. mill to obtain net return per thousand square feet. This net return was then multiplied by plywood yield per log to generate the conversion return of aspen veneer logs, by log size (Table 4). Plywood yield was developed by deducting 8 percent from the veneer yields of Figure 6. This deduction includes shrinkage and trim loss, but does not include sanding loss, since sheathing grades are generally not sanded.[11]

[10] It must be remembered that the costs in Table 2 are costs per thousand sq. ft. for *the average* log size of Sudburg's study, and thus do not represent production costs for logs either larger or smaller than the average log diameter. The calculating procedure develops production costs for each log size, using turning time from the time study and average output and average production costs from Sudburg's study.

* Turning time for a 12-inch log (Fig. 5) was divided into 60 to calculate logs processed per hour. This figure was then multiplied by the veneer yield for a 12-inch log (Fig. 6) to compute hourly production.

Table 4. Development of the conversion return of aspen veneer logs

(1) Diameter	(2) Production[1] per hour	(3) "Variable"[2] cost per M sq. ft.	(4) Total cost[3] per M sq. ft.	(5) Net return[4] per M sq. ft.	(6) Plywood[5] yield per log (sq. ft.)	(7) Conversion[6] return
inches	M sq. ft.				sq. ft.	
8	3.584	$44.75	$50.74	$16.19	23.0	$0.372
9	4.420	36.28	42.27	24.66	29.8	0.735
10	5.304	30.24	36.23	30.70	38.3	1.176
11	6.583	24.36	30.35	36.58	51.6	1.888
12	8.120	19.75	25.74	41.19	69.9	2.879
13	9.254	17.33	23.32	43.61	88.2	3.846
14	9.261	17.32	23.31	43.62	98.3	4.288
15	8.632	18.58	24.57	42.36	104.5	4.427
16	8.277	19.38	25.37	41.56	109.3	4.543

[1] Taken from column 6 of Table 3.
[2] Total variable costs/M sq. ft. (Table 2) times the average hourly production rate of Canadian mills (e.g., 8.120 M sq.ft./hr. times $19.75/M sq./ft.) divided by column 2.
[3] Column 3 plus the constant costs from Table 2.
[4] Value f.o.b. mill of aspen plywood (e.g. $66.93/M sq. ft.) minus column 4.
[5] From figure 6 less 8% waste for conversion of veneer to plywood.
[6] Column 5 times column 6 divided by 1000.

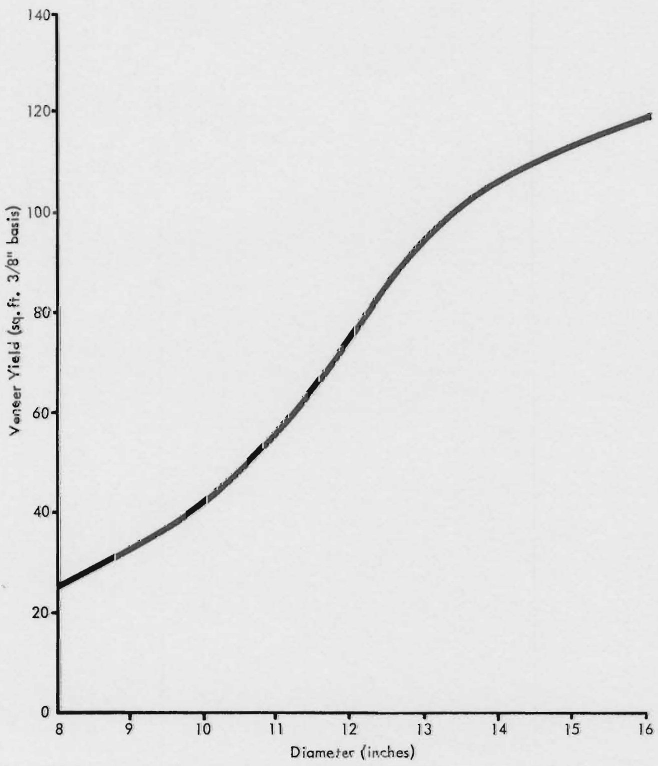


Figure 6. Relationship of veneer yield to diameter of aspen logs.

Residue Value: Because of recent developments in the utilization of residues, it seemed desirable to consider the value of cores, turnings, and trim as a source of pulp. Since the production of veneer requires debarked logs, no debarking costs are allocated to the production of residues. It is assumed that residue handling costs are the same whether or not the residue is sold, and that the plywood mill is on the same site as a pulp mill so that residue transportation costs are negligible. (Of course, transportation costs can be deducted from gross residue value when these costs are known.) In addition, by assuming the value of residue to be equal to that of peeled aspen pulpwood, chipping costs and the value of chips can be disregarded. Thus, under the above assumptions, the costs of utilizing the residue for pulp become zero, and the gross and net values are equivalent.

In veneer production only two products are produced by the lathe — veneer and residue in the form of turnings and cores. Since sheathing grades are not sanded, nearly all of the waste in aspen plywood production is chippable. Therefore, the residue volume is the total volume of a log less the volume of plywood produced. The residue value is residue volume times the value of peeled aspen pulpwood. However, as in the case of pulpwood value calculations, it was necessary to include a margin for risk and profit. Using a market value for peeled aspen pulpwood delivered to the mill of $18.50 per cord, a margin for risk and profit of nine percent, and a solid cubic foot volume per cord of 88.8,* a value of 22.9¢ per cubic foot was developed. This figure was then used in the calculation of residue values shown in Table 5.

Because fine residues (e.g., turnings) may have little utility in a pulpmill that uses chips from roundwood sources, the value of coarse residues (e.g., cores) has been presented separately in Table 6. This table shows three conversion return values of aspen logs. (1) first without residue values; then (2) with the residue value of only the core; and (3) with the total residue value. Core residue value was calculated assuming a 3.75-inch core diameter and using the residue value per cubic foot from Table 5. Total residue value was taken from Table 5. It is assumed that the unit value of fine residues is equal to that of coarse residues.

* 88.08 cubic feet per cord of peeled aspen was calculated from data collected in a study by the Mando Division of Boise Cascade Corp.

Table 5. Value of plywood residue

(1) Diameter	(2) Log volume[1]	(3) Veneer yield[2]	(4) Residue volume[3]	(5) Residue value[4]
inches	cu. ft.	cu. ft.	cu. ft.	
8	3.192	0.719	2.473	$0.566
9	3.915	0.931	2.984	0.683
10	4.976	1.197	3.779	0.865
11	5.979	1.612	4.367	1.000
12	7.188	2.184	5.004	1.146
13	8.208	2.756	5.452	1.249
14	9.935	3.072	6.863	1.572
15	11.036	3.266	7.770	1.779
16	12.799	3.416	9.383	2.149

[1] Taken from Table 1.
[2] Column 6, Table 4 converted to cubic feet.
[3] Column 2 minus column 3.
[4] Column 4 times the value of peeled aspen pulpwood in cubic feet. (e.g., $20.16/cord divided by 88.08 cu. ft./cord equals 22.9¢/ cu. ft.)

Table 6. Conversion return of aspen veneer logs, with and without residue values

(1) Diameter	(2) Value without residue[1]	(3) Core residue only[2]	(4) Value with total residue[3]
inches			
8	$0.37	$0.52	$0.94
9	0.73	0.88	1.42
10	1.18	1.32	2.04
11	1.89	2.03	2.89
12	2.88	3.03	4.03
13	3.85	3.99	5.10
14	4.29	4.43	5.86
15	4.43	4.57	6.21
16	4.54	4.69	6.69

[1] Taken from Table 4.
[2] Column 2 plus residue value of core (14.6¢)
[3] Column 2 plus column 5 of Table 5.

Sawlogs

Production Costs—ungraded lumber: The costs and values used in this section are based on the production of one-inch material on a conventional headrig. The hourly cost data presented in Table 7 are based on a study by Mischen and Smith.[6] The sawmill was equipped with a circular insert headsaw, an edger, and a trim saw. This mill is more or less representative of Minnesota's sawmills. Fuel, oil, and grease costs were adjusted to May 1967 using the wholesale price index for refined petroleum. The "all-commodities" wholesale price index was used to adjust office, overhead, and miscellaneous costs.

As in the case of veneer logs, it was necessary to develop costs by log size. To derive these costs, data from a time study conducted at the Red Lake Indian sawmill by the U.S. Forest Service, Northeast Forest Experiment Station, were used.* Sawing time was recorded to the nearest second for 77 eight-foot logs ranging from 8 to 16 inches in diameter. Mulitiple regression analysis of

* Unpublished data. On file at Northeast Forest Experiment Station, Upper Darby, Penn.

Table 7. Sawmill costs per hour

Item	Cost
Labor (6 men @ $2.00/hr.)	$12.00
Mill repair	0.45
Fuel, grease, and oil	2.61[1]
Office and overhead	3.06[1]
Miscellaneous	2.03[1]
Total cost per hour	$20.15
Total cost per minute	$ 0.336

[1] Based on Mischen and Smith (6), adjusted to May 1967 price levels.

Table 8. Costs per log for ungraded aspen lumber production

(1) Diameter	(2) Sawing time[1] without delay time	(3) Sawing time[2] with delay time	(4) Cost per log[3]
inches	minutes	minutes	
8	1.907	2.190	$0.735
9	2.070	2.378	0.798
10	2.252	2.586	0.868
11	2.453	2.818	0.946
12	2.675	3.072	1.032
13	2.915	3.348	1.124
14	3.175	3.647	1.225
15	3.175	3.966	1.332
16	3.752	4.309	1.447

[1] Figure 7 converted to minutes.
[2] Column 2 adjusted to include delay time (delay time of 14.9 percent of actual production time was used).
[3] Column 3 costs per minute from Table 7.

the data proved to be no more accurate than simple regression analysis. Thus, for the sake of simplicity, the following simple regression equation was used to predict sawing time:

$$Y = 77.454 + 0.5766X^2$$

where:
Y = sawing time in seconds, and
X = log diameter in inches (small end).

The equation proved highly significant at the 5 percent level, and had an "r" value of 0.679. Figure 7 presents the equation graphically.

These sawing times were converted to minutes and adjusted for nonscheduled delay time of 14.9 percent of sawing time.[6] The adjusted sawing time (Table 8) was multiplied by costs per minute (Table 7) to obtain costs per log, by log size.

Lumber Yield: Aspen sawlog yields are based on Wallin's study.[14] Data from 436 eight-foot logs, ranging from 8 to 16 inches in diameter, were analyzed using multiple regression techniques. The resulting equation was:

$$Y = 5.583 - 1.768X + 0.4241X^2$$

where,
Y = board foot yield, and
X = log diameter in inches (small end).

This equation proved to be highly significant at the 5 percent level, and had an "r" value of 0.928. The equation is presented graphically in Figure 8.

A survey of several of Minnesota's larger aspen lumber producers provided a weighted average market value of rough dry aspen lumber, f.o.b. mill. This value times the board foot yields from Figure 8 gives gross value by log size. The gross value less the production costs (Table 8) gives the conversion return for aspen sawlogs when used for the production of ungraded lumber (Table 9).

Residue Value: As with veneer log residues, sawlog residue value was assumed to be equal to that of peeled aspen pulpwood. Volume of chippable residue (Table 10) was determined by calculating the cubic foot volume of a squared cant, plus side lumber on larger diameters, and subtracting this volume and an allowance for kerf from the log volumes shown in Table 1.

Volume of cull lumber was estimated using Wallin's data.[14] By including cull lumber in the multiple regression analysis, the following formula was developed:

$$Y = 8.551 - 1.918X + 0.4226X^2$$

where:

Y = board foot yield including cull lumber, and

X = log diameter in inches (small end).

This equation proved highly significant at the 5 percent level, and had an "r" value of 0.931. The equation is

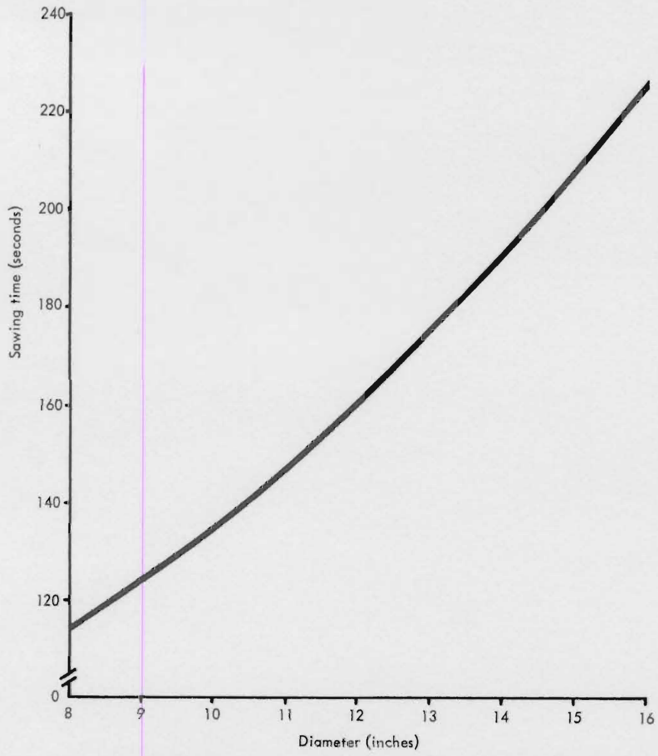


Figure 7. Relationship of sawing time to diameter of aspen logs.

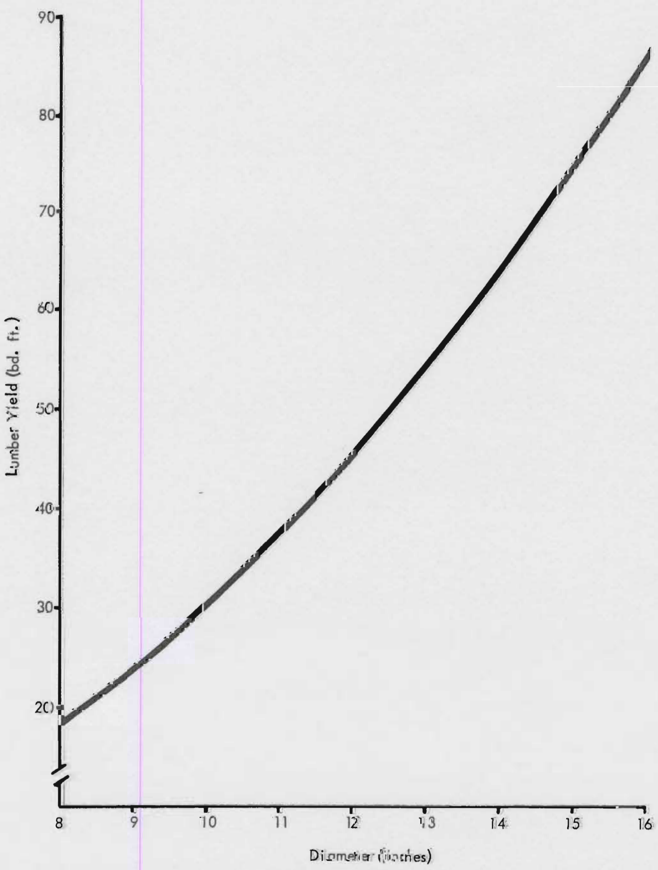


Figure 8. Relationship of lumber yield to diameter of aspen logs.

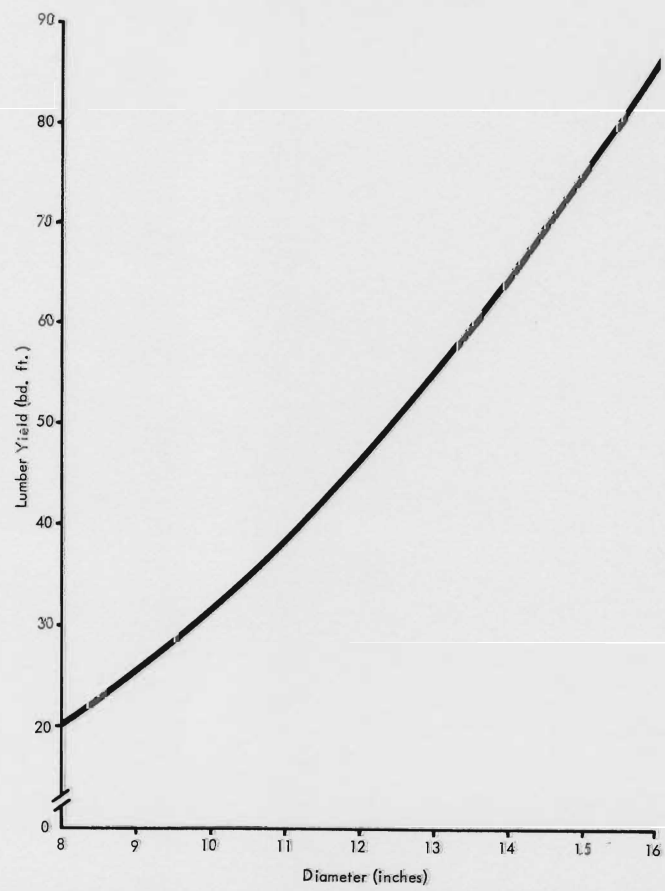


Figure 9. Relationship of lumber yield, including cull lumber, to diameter of aspen logs.

Table 9. Development of conversion return for aspen sawlogs when used for the production of ungraded lumber

(1) Diameter	(2) Yield per[1] log	(3) Gross converted[2] value per log	(4) Production[3] cost	(5) Conversion[4] return	(6) Residue[5] value	(7) Conversion[6] return with residue
inches	bd. ft.					
8	18.6	$1.170	$0.735	$0.435	$0.035	$0.47
9	24.0	1.513	0.798	0.715	0.048	0.76
10	30.3	1.910	0.868	1.041	0.065	1.11
11	37.4	2.359	0.946	1.413	0.090	1.50
12	45.4	2.863	1.032	1.831	0.119	1.95
13	54.3	3.419	1.124	2.295	0.152	2.45
14	64.0	4.029	1.225	2.804	0.194	3.00
15	74.5	4.693	1.332	3.361	0.244	3.60
16	85.9	5.409	1.447	3.962	0.301	4.26

[1] Taken from Figure 8.
[2] Column 2 times f.o.b. mill value of ungraded aspen lumber ($63.00/M bd. ft.) divided by 1000.
[3] From Table 8.
[4] Difference between column 3 and column 4.
[5] From Table 10.
[6] Sum of columns 5 and 6.

Table 10. Value of aspen lumber residue

(1) Diameter	(2) Volume of slabs[1] and edgings	(3) Volume of[2] cull lumber	(4) Total chippable[3] residue	(5) Residue[4] value	(6) Net[5] value
inches	cubic feet	cubic feet	cubic feet		
8	0.511	0.139	0.650	$0.149	$0.035
9	0.578	0.125	0.703	0.161	0.048
10	0.671	0.110	0.781	0.179	0.065
11	0.793	0.095	0.888	0.203	0.090
12	0.934	0.079	1.013	0.232	0.119
13	1.095	0.064	1.159	0.265	0.152
14	1.296	0.048	1.344	0.308	0.194
15	1.529	0.032	1.561	0.358	0.244
16	1.792	0.016	1.808	0.414	0.301

[1] Volume calculated to allow for a small degree of wane.
[2] Figure 9 minus Figure 8, converted to cubic feet.
[3] Sum of columns 2 and 3.
[4] Column 4 times the value of peeled aspen pulpwood (e.g., 22.9¢ per cubic foot).
[5] Column 5 less the debarking costs from Table 11.

presented graphically in Figure 9. Cull lumber is simply the difference between the yields given in Figure 9 and those given in Figure 8. The board foot yield of cull lumber was converted to cubic foot volume and is shown in Table 10. The volume of slabs, edgings, and cull lumber was multiplied by the residue value used for veneer residue to determine gross residue value (Table 10).

Since lumber production does not require debarked logs, it was necessary to allocate debarking costs to the production of saleable residues. These costs are shown in Table 11.

Using the adjusted sawing time for a 10.9-inch log,* number of logs processed per hour was calculated. This figure was used to determine labor costs per log. Power costs and maintenance and repair costs were assumed to be equal to the costs per ton of chips presented by Herrick and Christensen.[5] These costs were converted to costs per log, using the residue yields from Table 10, hourly number of logs processed, and a residue density of 31.5 pounds per cubic foot.* Depreciation, taxes, and insurance costs were converted to costs per log using the results of Herrick and Christensen.[5] These costs were summed to obtained gross debarking costs per log.

Table 11. Debarking costs per log

Item	Costs
Labor (@ $2.00/hr.)	9.325¢
Power	0.017
Maintenance and repair	0.022
Depreciation	3.127
Insurance and taxes	0.485
Gross costs	12.976¢
Less:	
Reduced saw maintenance	1.635¢
Net cost per log	11.341¢

* This is the average log size of the 438 logs studied by Wallin (14).

* A moisture content of 50 percent is assumed.

Table 12. Costs of producing graded aspen lumber

(1) Diameter	(2) Adjusted sawing time[1]	(3) Cost per log[2]
inches	minutes	
8	2.190	$0.808
9	2.378	0.878
10	2.586	0.955
11	2.818	1.040
12	3.072	1.134
13	3.348	1.236
14	3.647	1.346
15	3.966	1.464
16	4.309	1.591

[1] From Table 8.

[2] The sum of costs per minute from Table 7 plus $.0333 per minute times column 2 for the extra man required to grade lumber.

Because debarked logs are much cleaner than rough logs, less saw maintenance is required. This reduction in sawing costs is deducted from debarking costs to obtain net debarking costs per log (Table 11).

This cost was used in Table 10 to develop net residue value. The net residue value was added to the conversion return in Table 9 to develop conversion return by log size with saleable residue.

Production Costs—Graded Lumber: It is assumed that sawing for grade will not be practiced, and, therefore, sawing time is as presented in Table 8. Production costs will be increased by the addition of a grader. This change in production cost is reflected in Table 12.

Lumber Value—Graded Lumber: By analyzing grade yield data for the 436 logs used in the development of

Table 13. Gross value of graded aspen lumber

(1) Diameter	(2) Yield/log[1]	(3) Percent of[2] yield of #1 and better	(4) Percent of[3] yield of #2	(5) Percent of[4] yield of #3	(6) Yield of[5] #1 and better	(7) Yield of[6] #2	(8) Yield of[7] #3	(9) Gross[8] value
inches	bd. ft.	percent	percent	percent	bd. ft.	bd. ft.	bd. ft.	
8	18.6	27.6	35.2	37.2	5.1	6.5	6.9	$1.318
9	24.0	30.7	36.2	33.2	7.4	8.7	8.0	1.740
10	30.3	34.7	36.3	29.0	10.5	11.0	8.8	2.250
11	37.4	39.7	35.6	24.7	14.8	13.3	9.3	2.861
12	45.4	45.7	34.2	20.1	20.8	15.5	9.1	3.590
13	54.3	53.1	31.8	15.1	28.8	17.3	8.2	4.454
14	64.0	62.0	28.6	9.5	39.6	18.3	6.1	5.482
15	74.5	72.6	24.3	3.1	54.1	18.1	2.3	6.712
16	85.9	82.1	17.9	...	70.5	15.4	...	8.048

[1] From Figure 8.

[2] From Figure 10.

[3] From Figure 10.

[4] From Figure 10.

[5] Col. 2 times Col. 3.

[6] Col. 2 times Col. 4.

[7] Col. 2 times Col. 5.

[8] The sum of Col. 6 times $100/M, Col. 7 times $65/M, and Col. 8 times $55/M.

Table 14. Conversion return of aspen sawlogs when used for the production of graded lumber

(1) Diameter	(2) Gross value[1] per log	(3) Production[2] cost per log	(4) Conversion[3] return per log	(5) Net value[4] of residue	(6) Conversion return[5] with residue
inches					
8	$1.318	$0.808	$0.510	$0.035	$0.55
9	1.740	0.878	0.862	0.048	0.91
10	2.250	0.955	1.295	0.065	1.36
11	2.861	1.040	1.821	0.090	1.91
12	3.590	1.134	2.455	0.119	2.57
13	4.454	1.236	3.218	0.152	3.37
14	5.482	1.346	4.136	0.194	4.33
15	6.712	1.464	5.248	0.244	5.49
16	8.048	1.591	6.457	0.301	6.76

[1] From Table 13.

[2] From Table 12.

[3] Difference between column 2 and column 3.

[4] From Table 10.

[5] Sum of columns 4 and 5.

Figure 8, multiple regression equations were developed for: (1) percentage yield of lumber grade number 1 and better, (2) percentage yield of grade number 2, and (3) percentage yield of grade number 3. National Hardwood Lumber Grades were used in the grading process. The following equations were developed:

$$Y = 25.390 - 3.116X + 0.4077X^2$$

where:

Y = percentage yield of grade number 1 and better, and

X = log diameter in inches (small end).

This equation was significant at the 5 percent level, and had an "r" value of 0.423.

$$Y = 23.950 + 11.847X - 0.5788X^2$$

where:

Y = percentage yield of grade number 2, and

X = log diameter in inches (small end).

This equation was significant at only the 10 percent level, and had an "r" value of 0.171.

$$Y = 38.334 + 2.008X - 0.2909X^2$$

where:

Y = percentage yield of grade number 3, and

X = log diameter in inches (small end).

The equation for the prediction of grade number 3 percentage yield proved significant at the 5 percent level, and had an "r" value of 0.330. A graphic presentation of these three equations is found in Figure 10. Since the results of the above equations do not sum to 100 percent, it was necessary to adjust the small differences by proportional allocation. These adjusted percentages are presented in Table 13.

Grade yield percentages were multiplied by log yields to obtain board foot yields by grade for each log size. The grade yields were converted to gross log value using market values of $100 per thousand board feet for grade number 1 and better, $65 per thousand board feet for grade number 2, and $55 per thousand board feet for grade number 3 (Table 13). Production costs (Table 12) were deducted from these gross values to obtain the conversion return for aspen sawlogs when used in the production of graded lumber (Table 14). Net value of the chippable residue (Table 10) was included to develop the conversion return for aspen sawlogs used for graded lumber production when the residue was sold.

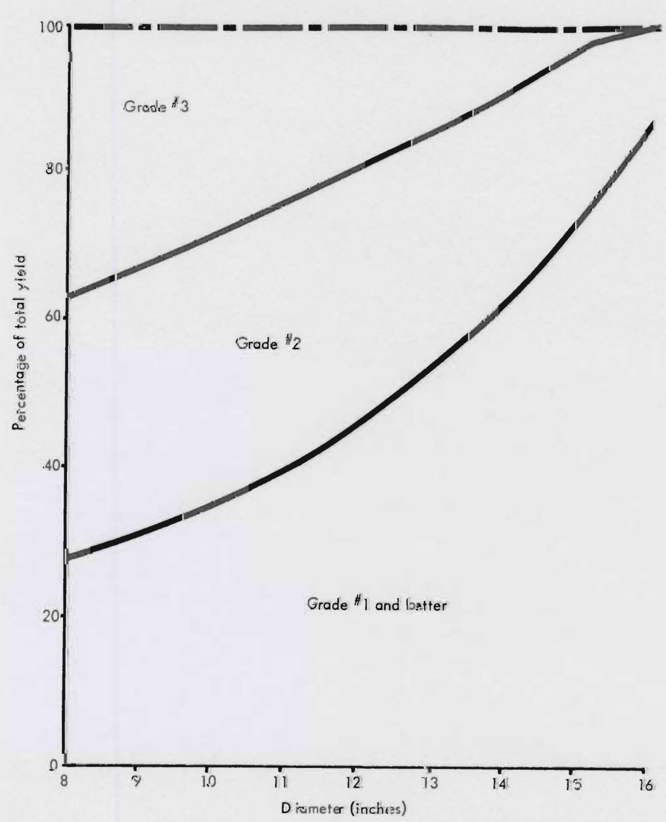


Figure 10. Relationship of percentage grade yields to diameter of aspen logs.

Comparison of Various Uses of Aspen Logs

Table 15 presents the conversion returns of the several uses of aspen which were considered in this report. Some discussion based on the table is required. First, plywood production, when all residues are sold, yields the highest conversion return for all log sizes studied except 16-inch logs. In this case, graded lumber production yields the greatest conversion return. However, if only the core residue from plywood production is sold, plywood production yields the largest conversion return for the log sizes 11 to 14 inches. For 9-, 10-, 15-, and 16-inch logs graded lumber production yields the largest conversion return. Pulp production yields the greatest return for 8-inch logs.

Conversion returns for pulp production, ungraded lumber production, graded lumber production, and plywood production are shown graphically in Figure 11. This shows that when residues are not sold: (1) pulp production is the most profitable use of 8-inch logs; (2) graded lumber production is the most profitable use of 9-, 10-, 15-, and 16-inch logs; and (3) plywood production is the most profitable use of 11- to 14-inch logs.

Figure 12 presents the conversion returns for the selected uses when residue values are included.* This graph shows that the inclusion of core residue values does not affect the most profitable use of any log size.

One must realize that Table 15 and Figures 11 and 12 are applicable only when the market prices, production costs, and assumptions used in this study are fulfilled. Since market prices and costs for the various uses change at different rates, it will be necessary to adjust the values in Table 15 when these changes occur. To accomplish this adjustment, the following formulas may be

* The residue values for plywood in Figure 12 include only the core value.

Table 15. Conversion returns for selected uses of aspen logs by diameter class

(1) Diameter	(2) Pulpwood[1]	(3) Ungraded[2] lumber without residue	(4) Ungraded[2] lumber with residue	(5) Graded[3] lumber without residue	(6) Graded[3] lumber with residue	(7) Plywood[4] without residue	(8) Plywood[4] with cores	(9) Plywood[4] with all residues
inches								
8	$0.66	$0.44	$0.47	$0.51	$0.55	$0.37	$0.52	$0.94
9	0.81	0.72	0.76	0.86	0.91	0.73	0.88	1.42
10	1.03	1.04	1.11	1.30	1.36	1.18	1.32	2.04
11	1.24	1.41	1.50	1.82	1.91	1.89	2.03	2.89
12	1.49	1.83	1.95	2.46	2.57	2.88	3.03	4.03
13	1.71	2.30	2.45	3.22	3.37	3.85	3.99	5.40
14	2.07	2.80	3.00	4.14	4.33	4.29	4.43	5.86
15	2.29	3.36	3.60	5.25	5.49	4.43	4.57	6.21
16	2.66	3.96	4.26	6.46	6.76	4.54	4.69	6.69

[1] From Table 1.
[2] From Table 9.
[3] From Table 14.
[4] From Table 6.

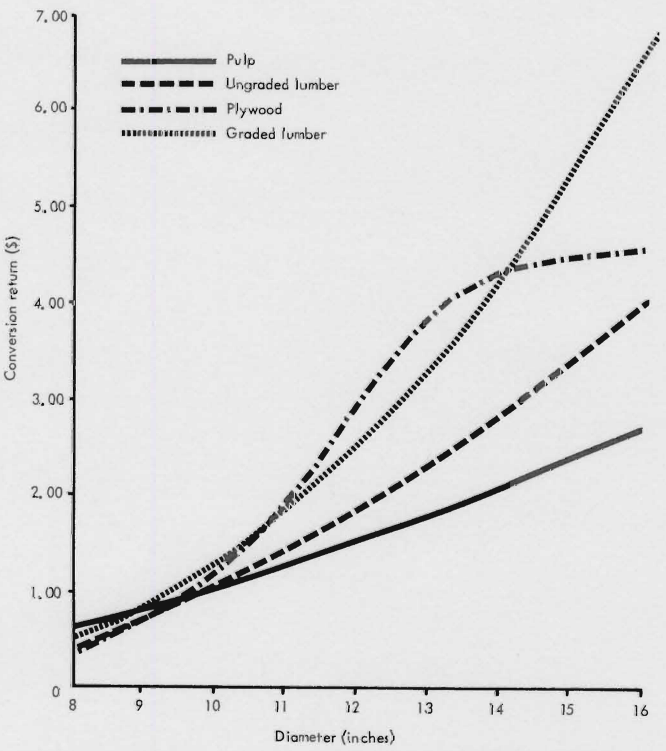


Figure 11. Comparison of the conversion returns for selected uses of aspen logs excluding residue values.

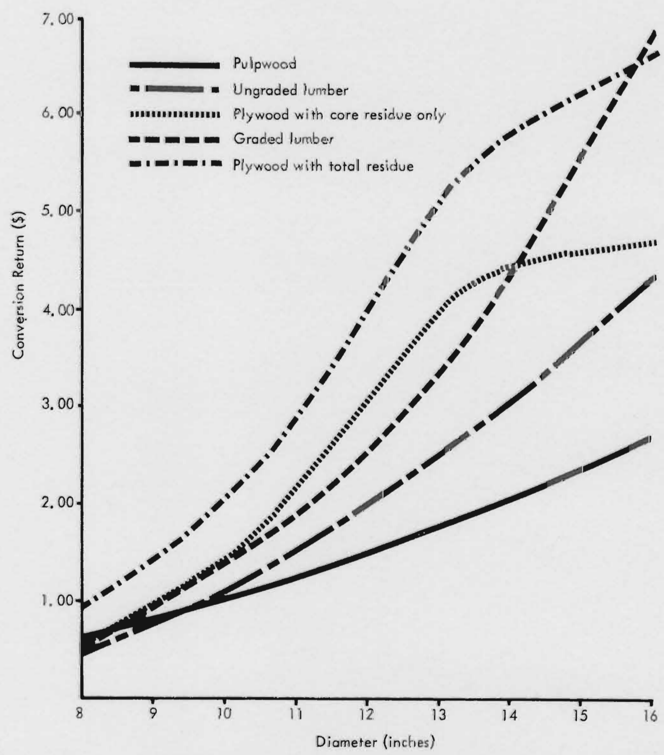


Figure 12. Comparison of conversion returns for selected uses of aspen logs including residue values.

used as general guides for calculating the conversion returns of the selected uses of a given aspen log:

I. The conversion return for *pulp production*:

$$C.R._1 = V_1 \frac{MV_1 (1 + Mp)}{78.46}$$

where,

$C.R._1$ = conversion return of pulp production,

V_1 = log volume in cubic feet (Table 1),

MV_1 = market value of aspen pulpwood delivered to the mill,

Mp = margin for risk and profit.

II. The conversion return for *plywood production*:

$$C.R._2 = Y_2 (MV_2 - FC) - \frac{AP \times VC \times PT}{60}$$

where,

$C.R._2$ = conversion return of plywood production,

Y_2 = plywood yield in thousand square feet,

MV_2 = market value of aspen plywood f.o.b. mill

FC = fixed cost per thousand square feet,

AP = average hourly production of plywood in thousand square feet.

VC = average variable costs per thousand square feet.

PT = production time per log in minutes (Column 3, Table 3)

The above formula could be shortened to:

$$C.R._2 = Y_2 (MV_2 - VC - FC).$$

III. The conversion return for *ungraded lumber production*:

$$C.R._3 = 2(MV_3 \times Y_3) - (ST \times C_3)$$

where,

$C.R._3$ = conversion return of ungraded lumber production.

MV_3 = market value of ungraded rough dry aspen lumber f.o.b. mill.

Y_3 = yield of aspen logs in thousand board feet (Figure 11).

ST = sawing time per log (Table 8).

C_3 = production costs per minute.

IV. The conversion return for *graded lumber production*:

$$C.R._4 = Y_4 (MV_4 \times P_4) + (MV_5 \times P_5) + (MV_6 \times P_6) - (ST \times C_4)$$

where,

$C.R._4$ = the conversion return of graded lumber production.

Y_4 = yield of aspen logs in thousand board feet (Figure 4).

MV_4 = market value of No. 1 and better aspen lumber, f.o.b. mill.

MV_5 = market value of No. 2 aspen lumber, f.o.b. mill.

MV_6 = market value of no. 3 aspen lumber, f.o.b. mill.

P_4 = percentage of total yield which is grade No. 1 and better.

P_5 = percentage of total yield which is grade No. 2.

P_6 = percentage of total yield which is grade no. 3.

ST = sawing time per log (Table 8).

C_4 = production costs per minute.

V. The *value of residues*:

$$VR = V_7 \left[\frac{MV_7 (1 + Mp)}{88.08}\right] - T - C$$

where,

VR = value of residue.

V_7 = volume of residue in cubic feet (Table 10 for lumber and Table 5 for plywood).

MV_7 = market value of peeled aspen pulpwood delivered to the mill.

Mp = margin for risk and profit.

T = cost of transporting the residue to the pulp mills.

C = cost of debarking (Table 11) used only for sawlogs.

It should be pointed out that these formulas are simply a shorthand expression of the conversion return procedures and data discussed earlier in this report. Appendix 1 contains a numerical example of the use of these formulas to compare profitability of the various uses.

Conclusion

The analytical approach of this study may serve as a base for the decisions of both log purchasers and log sellers. Coupled with knowledge of growth rates, harvesting costs, and other costs, this study could provide the timber grower with information necessary for decisions concerning rotation, thinning, and stand conversion.

It is interesting to note that for all diameters studied the conversion return was greater for graded lumber than for ungraded lumber. This agrees with the suggestion of Thompson and Rathbun[12] that greater profits could be realized if graded lumber were sold rather than mill-run lumber, as is now commonly done.

From a broader point of view, this analysis points out some rather large differences in the conversion returns for various uses of aspen logs. These differences indicate that making pulp from the larger sized logs may be a poor use when markets exist for other products. Log sorting by diameter offers a more efficient use of the harvested aspen resource. Concentration yards or integrated mills could help allocate the larger aspen logs to more profitable uses. This allocation process would likely result in higher returns per unit harvested, to the benefit of the timber industry and the entire economy of the state.

As new markets develop and new production processes evolve, conversion return analysis can help guide log allocation decisions, and, ultimately, timber management decisions.

Appendix

The following hypothetical situation is used to illustrate how the adjustment process, discussed on page 17, is used. The following deviations from the values used in the study are assumed: (1) the market value of pulpwood is $0.50 per cord greater; (2) the fixed costs of plywood production are $0.50 per thousand square feet less; (3) the price for ungraded aspen lumber is $2.00 per thousand board feet greater; (4) the price for aspen No. 1 and better lumber is $10.00 per thousand board feet greater; and (5) the costs of production for both graded and ungraded lumber is $1.00 per thousand board feet greater. These values and the unchanged values from the study are used to calculate the conversion returns for the various uses of 10-inch logs.

I. Pulp production

$$C.R._1 = V_1 \frac{MV_1 (1 + Mp)}{78.64}$$

$$= 4.976 \frac{16.00 (1 + .09)}{78.64}$$

$$= \$1.10$$

II. Plywood production

$$C.R._2 = Y_2 (MV_2 - FC) - \frac{AP \times VC \times PT}{60}$$

$$= .0416 (66.93 - 5.49) - \frac{8.12 \times 19.75 \times .471}{60}$$

$$= 2.56 - 1.26$$

$$= \$1.30$$

Residue value of plywood production

$$VR = V_7 \frac{MV_7 (1 + Mp)}{88.08}$$

$$= 3.676 \frac{19.00 (1 + .09)}{88.08}$$

$$= \$0.86$$

Therefore the conversion return for aspen plywood is $2.16 when all residues are included, and $1.45 when only the core residue is included.

III. Ungraded lumber production

$$CR_3 = (MV_3 \times Y_3) - (ST \times C_3)$$

$$= (65.00 \times .0303) - (2.586 \times .352)$$

$$= \$1.06$$

Residue value of lumber production

$$VR = V_7 \left[\frac{MV_7 (1 + Mp)}{88.08}\right] - C$$

$$= .781 \left[\frac{19.00 (1 + .09)}{88.08}\right] - .11$$

$$= \$0.07$$

Therefore, the conversion return when residues are considered is $1.13 for ungraded lumber production.

IV. Graded lumber production

$$CR_4 = Y_4 (MV_4 \times P_4) + (MV_5 \times P_5) + (MV_6 \times P_6) - (ST \times C_4)$$

$$= .303 (110 \times 34.7) + (65 \times 36.3) + (55 \times 29.0) - (2.586 \times .386)$$

$$= \$1.35$$

Including the residue values, the conversion return for graded lumber production would be $1.42.

By making calculations of this nature, the procedure developed in this study can be adapted to changing conditions as these conditions develop.

Literature Cited

1. Blyth, James E. 1967. *Rising Pulpwood Prices Stimulate Largest Lake States Pulpwood Harvest.* U.S. Forest Service, North Central Forest Experiment Station Research Note NC-31. 3 p.

2. Bulgrin, E. H., K. A. McDonald, and C. L. Vaugham. 1966. *Veneer Yields from Lake States Quaking Aspen.* United States Forest Products Laboratory Research Paper RPL-59. 8 p.

3. Duerr, W. A. 1960. *Fundamentals of Forestry Economics.* New York, McGraw-Hill. 579 p.

4. Guttenberg, Sam and W. A. Duerr. 1949. *A Guide to Profitable Tree Utilization.* U.S. Forest Service, Southern Forest Experiment Station Occasional Paper No. 114. 18 p.

5. Herrick, O. W. and W. W. Christensen. 1967. *A Cost Analysis of Chip Manufacture at Hardwood Sawmills.* U.S. Forest Service, Northeast Forest Experiment Station Research Paper NE-69. 14 p.

6. Mischen, R. M., and Richard Smith. 1964. *Sawmill Efficiency in the Eastern Ozark Region.* Missouri Agriculture Experiment Station Bulletin No. 860. 31 p.

7. Rawie, C. D. and J. E. Blyth. 1967. *Northern Minnesota Lumber Production Declining From 1960 to 1965.* U.S. Forest Service, North Central Forest Experiment Station Research Note NC-30. 4 p.

8. Segur, John A. 1967. *Protecting Our Wood Supply.* Journal of Forestry 65(7):458-463.

9. Stone, Robert N. 1966. *A Third Look at Minnesota's Timber.* U.S. Forest Service, North Central Forest Experiment Station Resource Bulletin NC-1. 64 p.

10. Sudburg, A. E. J. 1966. *Poplar Veneer and Plywood Estimated Production Costs,* September 19, 1966. Canadian Department of Industry. Ottawa. 3 p.

11. Sydneysmith, Sam and P. H. Pearse. 1966. *Method for Allocating Logs Among Several Utilization Processes.* Forest Products Journal 16(9):87-98.

12. Thompson, R. D. and H. F. Rathbun. 1966. *Markets Available for Minnesota Aspen Lumber.* Minnesota Forestry Notes No. 172. 2 p.

13. U.S. Forest Service. 1966. *Timber Trends in the United States.* U.S.D.A., Forest Service, Forest Resource Report 17. 235 p.

14. Wallin, Walter B. 1957. *The Influence and Importance of Defects and Log Grades on Lumber Grade Yield from Aspen Logs.* Ph.D. Thesis. University of Minnesota. 213 p.