1983

Production and Product Recovery for Complete Tree Utilization in the Northern Rockies

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Production and Product Recovery for Complete Tree Utilization in the Northern Rockies

John M. Mandzak, Kelsey S. Milner, and John Host

THE AUTHORS

JOHN M. MANZAK is research and development supervisor for Champion Timberlands, Milltown, Mont. He was responsible for planning and supervising operations and logistics on this study.

KELSEY S. MILNER is a research forester for Champion Timberlands, Milltown, Mont. He was responsible for data collection and analyses for this study.

JOHN R. HOST is a research forester, Improving Wood Resource Utilization Work Unit, Intermountain Forest and Range Experiment Station, Forestry Sciences Laboratory, Missoula, Mont. He was responsible for planning and coordinating this study.

ACKNOWLEDGMENTS

This study was a cooperative effort between the Intermountain Forest and Range Experiment Station and Champion Timberlands. The Intermountain Station provided supplementary funding, study planning, and report publication. Champion Timberlands provided the work sites, personnel, and equipment for the study, along with a conscientious effort to do a good job. This study could not have been undertaken without the help and cooperation of Hahn Machinery, Incorporated, of Two Harbors, Minn., and Strong Manufacturing Company of Remus, Mich. Both manufacturers provided new test machines, competent operators, and more than adequate support.

St. Onge Logging Company of Missoula, Mont., provided skidding and loading equipment, with skilled and conscientious operators. Midnight Logging Company of Huson, Mont., provided a Melroe Bobcat feller-buncher and a skilled operator.

RESEARCH SUMMARY

Profitable management of second-growth timber in the Northern Rockies will be influenced by the economics of small timber harvesting. The small average stem size of second-growth stands coupled with low product values tends to make current logging systems uneconomical in many areas.

In this study, a whole-tree harvesting system designed to produce logs and chips was evaluated on four sites, each with a different silvicultural prescription. The system consisted of: feller-bunchers, grapple-equipped rubber-tired skidders, a tree processor, a whole-tree chipper, and a hydraulic log loader. Production rates for the overall system and for its various components were developed with time-motion study techniques. Variation in productivity between study areas was analyzed with respect to stand and site characteristics.

Results of this study indicated: (1) The system can produce chips and logs at acceptable rates for a range of site and stand conditions. Daily production ranged from 89 to 193 tons (81 to 176 tonnes) of logs and 119 to 178 tons (108 to 162 tonnes) of chips. (2) The proportions of chipable and sawable material available in the stand affect overall system productivity and productivity of system components. (3) The complete utilization of slash by the system provided additional forest management benefits. These included reduction in bark beetle hazard, reduction of future site preparation activities (especially logging), and improved appearance of harvested stands.

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CONTENTS

INTRODUCTION

The harvest of small timber of commercial size has historically been a problem due to relatively high labor costs per unit coupled with low product values. Small logs are typically processed into studs (8–9” × 2–4”, 2–6”, etc.) because demand and market price are highly fluctuating. The process of harvesting and conversion of small timber to studs is difficult and marginally profitable. Nevertheless, small timber represents a relatively large percentage of the volume of timber available in the Rocky Mountain area, and this percentage will increase in the coming decades as old-growth timber stands are converted to managed stands. If costs of logging small trees were reduced, the ultimate profitability of the processing of framing material could be improved dramatically.

Stands of small timber are of two basic types. There is the relatively old stand, with small-diameter trees that have little potential for further net growth. Such stands occupy valuable growing space yet contribute little to site productivity. Stagnant, old-growth lodgepole pine (Pinus contorta var. latifolia Engelm) and stands of true fir (Abies spp.) are common examples. The harvesting and subsequent regeneration of these stands, usually by clearcutting, would bring these areas back into production.

The second type of small timber stand is the relatively young, overstocked stand with some stems of small commercial size. Partial cutting, such as a commercial thinning, would permit added growth on the remaining stems and prevent the stagnation of the first type of stand. Such partial cuts in young ponderosa pine (Pinus ponderosa Doug. ex Laws.) stands would also help prevent buildup of bark beetle populations by maintaining tree vigor. These young, overstocked stands are of critical importance because a shortage of merchantable timber is expected after the old-growth has been harvested. The faster these young stands are brought to merchantable sizes, the shorter will be the time interval with a lower harvesting rate. It is, therefore, highly desirable that young stands are managed so as to fully utilize the growth potential of the site.

Management of small timber is also affected by the demand for wood fiber suited to the manufactures of paper, fiberoad, particleboard, or hog fuel. Historically, mill trimmings and waste have been the source of such material. However, during slack market periods when lumber and veneer production is reduced, the supply of such waste material is also reduced. Small-sized timber could help satisfy the raw material shortfall during these intervals.

This study was undertaken to explore one alternative for utilizing polelogging residues and to determine the feasibility of generating boiler fuel from thinning operations for the Forest Service and Champion Timberlands, respectively. The study took place during August 1980. It is one of a series of studies dealing with utilizing material from thinning operations in western Montana.

Study Objectives

The objective of this study was to test the feasibility of a mechanical harvesting system designed to process small logs and produce chips suitable for hog fuel and pulp and paper. The logging system is shown schematically in figure 1. Specific goals were:

1. Compare the productivity and advantages of falling and prebranching trees for grapple skidders by a feller-buncher (tree shears) relative to conventional sawyer falling, choker-skidding logging methods.
2. Compare the quality of logs manufactured by a tree processor to that for logs produced by conventional methods. Also, determine production rates for the tree processor.
3. Compare the loading time for small logs delimbed and bucked by a tree processor to those for logs delimbed in a conventional system.
4. Evaluate the tree processor-chipper logging system as a forest management tool. Specific tasks to be considered include:
   a. Thinning stands on a commercial basis.
   b. Clearing stands of small trees for regeneration on a commercial basis.
   c. Reducing insect damage potential in ponderosa pine stands.
shelterwood cut. Leave trees were identified. The terrain was a flat bench with about a 5 percent slope. This stand was chosen to represent a relatively light harvest volume shelterwood cut.

The cruise summary for the block was:

<table>
<thead>
<tr>
<th>Item</th>
<th>Per acre</th>
<th>Per block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal area (ft²)</td>
<td>99</td>
<td>1,980</td>
</tr>
<tr>
<td>Number - chipable stems &lt; 9” d.b.h.</td>
<td>278</td>
<td>5,560</td>
</tr>
<tr>
<td>- saw log stems &gt; 9’ d.b.h.</td>
<td>85</td>
<td>1,700</td>
</tr>
<tr>
<td>Total trees</td>
<td>363</td>
<td>7,260</td>
</tr>
<tr>
<td>Volume - chipable trees (ft³)</td>
<td>579</td>
<td>11,580</td>
</tr>
<tr>
<td>- saw log trees (ft³)</td>
<td>1,418</td>
<td>28,560</td>
</tr>
<tr>
<td>- total (ft³)</td>
<td>1,997</td>
<td>39,940</td>
</tr>
<tr>
<td>- tops of saw log trees (ft³)</td>
<td>112</td>
<td>2,240</td>
</tr>
<tr>
<td>- Scribner - 6” top d.b.h. (bd.ft.)</td>
<td>4,280</td>
<td>85,600</td>
</tr>
<tr>
<td>- per tree (bd.ft.)</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Area (acres)</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

d. Eliminating slash disposal costs through 100 percent tree utilization.

e. Maintaining air quality by eliminating slash burning.
f. Improving stand access and recreating greater volume.

g. Improving aesthetics of inventoried areas.

STUDY METHODS

Study Area Description:

Figure 1 shows the location of the four cutting blocks near Missoula, Mont. The blocks are oriented with respect to timber type, terrain, and cutting method, reflecting the diversity of conditions on which the logging system might be applied.

Marking, Cruising, and Block Layout:

The Gold Creek logging block was clearcut.

Therefore, only the boundaries were marked. Leave trees on the remaining blocks were marked with blue paint. Rings were painted around the tree at breast height and 30 just above the groundline. So these operators could identify the leave trees from all directions. Conventional leave marking for Champion Timberlands consists of blue paint and white tapes. Blocks were cruised to ensure that the stems were curtained characteristically, especially in regard to area-size distribution.

Arkansas Creek Block: This 20-acre (8 ha) logging block was established in a young growth stand of approximately 80 percent ponderosa pine, 15 percent Douglas-fir (Pseudotsuga menziesii var. glauca (Bong) Franco) and 5 percent western larch (Larix occidentalis Nutt.). The cutting was designed a

Figure 1. Flow diagram of a harvesting system for logs and whole-tree chips true, using a Hierarch Forest Harvester in conjunction with a Triton Model 10-18 whole-tree chopper.

Gold Creek block: This 12.7-acre (5.1-ha) logging block was established in a 70-year-old lodgepole pine stand. The species mix was approximately 98 percent lodgepole pine and 2 percent ponderosa pine. The stand was clearcut with the exception of scattered, large-old-growth ponderosa pine, larch, and a few young-growth ponderosa pine of good form. The terrain was relatively flat, ranging from 5 to 25 percent on small areas of steeper ground. This block is representative of stagnant lodgepole pine stands in the Northern Rockies.

The cruise summary for the block was:

<table>
<thead>
<tr>
<th>Item</th>
<th>Per acre</th>
<th>Per block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal area (ft²)</td>
<td>137</td>
<td>1,740</td>
</tr>
<tr>
<td>Number - chipable stems &lt; 9” d.b.h.</td>
<td>265</td>
<td>3,365</td>
</tr>
<tr>
<td>- saw log stems &gt; 9’ d.b.h.</td>
<td>187</td>
<td>3,725</td>
</tr>
<tr>
<td>Total trees</td>
<td>452</td>
<td>5,740</td>
</tr>
<tr>
<td>Volume - chipable trees (ft³)</td>
<td>1,531</td>
<td>19,444</td>
</tr>
<tr>
<td>- saw log trees (ft³)</td>
<td>3,583</td>
<td>45,594</td>
</tr>
<tr>
<td>- total (ft³)</td>
<td>5,114</td>
<td>64,948</td>
</tr>
<tr>
<td>- tops of saw log trees (ft³)</td>
<td>945</td>
<td>12,001</td>
</tr>
<tr>
<td>- Scribner - 6” top d.b.h. (bd.ft.)</td>
<td>11,504</td>
<td>146,101</td>
</tr>
<tr>
<td>- per tree (bd.ft.)</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Area (acres)</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

**Sunflower Road Block:** This 4.5-acre (1.8-ha) logging block was established in a young western larch stand. The species mix was estimated to be 80 percent western larch, 10 percent lodgepole pine, and 10 percent Douglas-fir. The terrain consisted of a smooth slope of about 25 percent throughout. The block represented a commercial thinning of fairly light log volume on slopes near the maximum capability for conventional tree shears and rubber-tired skidders. The area also had a restricted landing area and provided an opportunity to gain experience and data on the processing of western larch.

**Figure 2:** Location of study blocks on Champion International lands in western Montana.

**The cruise summary was:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Per acre</th>
<th>Per block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal area (ft²)</td>
<td>147</td>
<td>661</td>
</tr>
<tr>
<td>Number - chipable stems &lt; 9” d.b.h.</td>
<td>441</td>
<td>1,984</td>
</tr>
<tr>
<td>- saw log stems &gt; 9’ d.b.h.</td>
<td>117</td>
<td>526</td>
</tr>
<tr>
<td>Total trees</td>
<td>558</td>
<td>2,511</td>
</tr>
<tr>
<td>Volume - chipable trees (ft³)</td>
<td>1,610</td>
<td>7,245</td>
</tr>
<tr>
<td>- saw log trees (ft³)</td>
<td>2,830</td>
<td>12,735</td>
</tr>
<tr>
<td>- total (ft³)</td>
<td>4,440</td>
<td>19,980</td>
</tr>
<tr>
<td>- tops of saw log trees (ft³)</td>
<td>496</td>
<td>2,232</td>
</tr>
<tr>
<td>- Scribner - 6” top d.b.h. (bd.ft.)</td>
<td>11,441</td>
<td>51,684</td>
</tr>
<tr>
<td>- per tree (bd.ft.)</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Area (acres)</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

**Sheep Flats blocks:** These blocks were established of 17.5, 5.6, and 20 acres (7.1, 2.3, and 8.1 ha), respectively. The species mix was approximately 80 percent ponderosa pine and 20 percent Douglas-fir. Stands were generally less than 5 percent, with the exception of about 2 acres (0.8 ha) with slopes up to 15 percent. Leave trees were marked and the dominant cutting practice was the shelterwood method with some commercial thinning. These blocks were representative of a stand with large forestable trees that would also be attractive to conventional logging operations.
Logging Equipment and Methods

Feller-bunchers.—An International track-mounted feller-buncher (Model 366-B) did most of the felling and bunching for the study. A Model Bobcat (Model 1070) feller-buncher was also used on the Gold Creek lodgepole pine and on the Sheep Flats block. The Bobcat shear had an accumulator to hold two or three cut stems, while the International did not. Conventional powertows were used to fell trees 18 inches (45.7 cm) d.b.h. and larger that were too large for the feller-bunchers. Sawyers also limbed and bucked the first log out of very large trees. The bunches were not sorted according to merchantability. Bunched were oriented first toward the landing to facilitate skidding as shown in figure 3. Limbed trees were sheared to a 6-inch (15.2 cm) lower d.b.h. limit.

Skidding machines.—Two John Deere Model 640 rubber-tired skidders were used to do the skidding. One skidder was equipped with a grapple and the other with chokers. The grapple machine operated primarily on and close to the landing, while the choker machine was used for pulling the skidded trunks away from the grapple in the back of the units. This separation of the skidders eliminated the hazardous unhooking of chokers. Also, there was less delay with the grapple skidder at the machine-crowded landing.

Tree processor.—The machine used was a new Hahn Tree-length Harvester equipped with a control cab. One operator controlled the log processing while the other operator controlled the grapple, which fed trees to the processor and also helped sort bunches and feed the chipper.

Whole-tree chippers.—A Trelan Model DL-18 whole-tree chipper manufactured by Champion (Huntington Park, Calif.) equipped with cabs for both operators. The chipper was equipped with a hopper located under the machine.

Log loading.—A truck-mounted Husky Brute hydraulic loader loaded the logs produced. The loader was normally stationed next to the tree processor and sorted logs when a truck was not available.

Chip vans.—Chip vans were used to transport hog fuel chips. The vans were not disconnected from the tractors when they were filled, although this would be an option. Four types of vans were used in the study, described in appendix A. Figure 4 shows the landing on Sheep Flats block; figure 5 illustrates the landing schematically. The landing could be (and was) split up if either the tree processor or the chipper was unavailable, or if landings were too small to accommodate all of the equipment.

Figure 4—Landing at the Sheep Flats block.

Figure 3—Bunched trees oriented toward landing.

Figure 5—Orientation of equipment on the landing as used in the study.

Crew Members and Organizations

Hahn Manufacturing Co. supplied two operators who had some experience with the tree processing machine. We trained the operator responsible for cutting out logs to recognize the tree species and the corresponding log lengths desired. Strong Manufacturing Co. supplied an experienced operator for the chipper. A logger under hourly contract provided the two tree felled skidders, hydraulic loader, sawyer, and an operator for the International feller-buncher. The International tree sheared was rented from a local equipment dealer. The mechanics, mechanics-supervisor, and operator were provided by a local contract logger. Champion Timbersland furnished data collectors, who were trained and supervised by the USDA Forest Service study co-riminator. Crew supervision was provided by a crew foreman and timber processing foreman. The operators and timber processors estimated down time, and used their own equipment. Log volumes were cooperatively computed to take advantage of various ideas and skills. Most crew members were highly motivated and production conscious.

Data Collection

Time study methods.—Detailed time data were collected at each study area for the shearing, skidding, tree processing, and chipping phases of the logging system. For a sampling period the activity of each machine was timed with a stop watch to the nearest 0.01 minute and the production of each machine tallied. The sampled time for each machine was broken into two parts: that spent in active production and that spent in nonproductive activities, termed downtime. Downtime was further subdivided into categories so that causes of lost production could be identified. The data collected for each machine are described below.

Feller-bunchers.—Feller-buncher production for the tree shears was in tree car per minute for the sample period. Merchantable and unmerchantable stems were tallied separately. The time spent cutting, the time spent moving, and the downtime were recorded. Periodically, the time spent actually cutting a given stem was recorded for a range of basal diameters. The estimated distance covered moving from stump to tree was also recorded.

Skidders.—Two persons were needed to collect skidder data, a skidding operator and a forward buncher. At each stop watch, time was recorded, time spent cleaning the area, and time spent moving stockpiled turns out to the tree processor and chipper. The field observer recorded loaded turn time, turn number of the log, hook time, round trip time, and skid distance. These observations were then combined on a per-turn basis to yield production rates of stems per day and turn per turn.

Tree processor.—A single observer recorded lapsed clock time, number of trees handled, number of logs produced, and downtime for the tree processor. Peninsular processing time per turn was recorded for a range of diameters and species. Production was in logs produced per minute.

Chippers.—A single observer recorded lapsed time, number of merchantable stems, number of unmerchantable stems, and downtime for the chipper by van load produced during the sample period. Logs and limbs were not counted. Production was in number of stems processed per minute or units of chips produced per unit of time. The observer recorded arrival and departure of chip vans and log trucks and noted other activities or characteristics of the operation that affected production.

Miscellaneous.—The data collection was carried out in such a manner that:

1. Safety of all personnel was insured.
2. Production personnel did not have to worry about the safety of studied personnel.
3. The production process was not affected by the study process.
4. Production tallies.—Each load of logs received a receipt or "ticket book" number according to Champion Timbersland's practice. Every load of logs was weighed scaled at the mill log yard. Scaling frequency (number of loads scaled versus total number of loads) varied from block to block, depending on the number of loads expected. The scaling frequency was 50 percent on the larger blocks and 100 percent on the smaller blocks. Log volume in Scribner board feet was obtained from the scaling data.

Each van load of hog fuel also received a "ticket." Net weights, gross weights, and number of "hog fuel units" were determined by standard accounting and sampling procedures at the unloading facility of a Champion International pulp mill.

Log quality.—Log quality reports were prepared in accordance with standard company procedures. Data were, therefore, available to compare logs manufactured with a tree processor to normally processed logs. Log lengths, broken ends, excessive bucking, limbs, etc., were evaluated in such reports.

Chip quality.—Samples of chips were analyzed for important to papermaking. The percentage of bark content and the percentage of chips over and under a desired size range were determined. Such properties are not critical if the product is used for hog fuel.

RESULTS

System Productivity

Table 1 shows the overall production of hog fuel and logs realized from each cutting block. On a per-acre basis, production of hog fuel (tons/acre) and logs (M bd ft./acres) varied considerably among the cutting blocks. The least percent of log volume realized was in the block at Sunflower Road and Arkansas Creek which generated the highest per-acre production of hog fuel followed by the shelterwood cutting at Sheep Flats. The order of log production in the partial clear cut was reversed. The Sheep Flats operation produced 50 percent more log volume than did the other partial cutting operations at Sunflower Road and Arkansas Creek.

To more accurately assess the differences in system productivity, it is useful to consider production per unit of labor rather than production per acre. Table 2 shows production in tons per man-hour (per turn—total time—delay time) for hog fuel and logs for each cutting block.

When productivity is based on time rather than acres, the rankings are changed. This is because table 2 data indicate how well the system processed the flow of raw materials per unit of labor rather than what was available per acre for the system to process.

The results in table 2 suggest that the system is most productive, in terms of tons per man-hour, when logs are produced at a rate equal to or greater than that for hog fuel. Two factors that significantly affect these rates are production (1) raw material characteristics and (2) system component interactions.
Table 1—Summary of study areas and production volumes

| Area                  | Description | Species mix | Production
<table>
<thead>
<tr>
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<tbody>
<tr>
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<td></td>
<td></td>
<td>Harvest block</td>
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<td>Fuel Logs</td>
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<td></td>
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<td></td>
<td>8-9 d.b.h.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production</td>
</tr>
</tbody>
</table>

| Area                  | Description | Species mix | Production
<table>
<thead>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Processor</td>
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<td></td>
<td></td>
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<td>Chipper</td>
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<td></td>
<td></td>
<td>Chipper</td>
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<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Table 2—Comparison of labor productivity for different logging blocks

| Area                  | Description | Species mix | Production
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Harvest block</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Fuel Logs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8-9 d.b.h.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production</td>
</tr>
</tbody>
</table>

Table 3—Distribution of harvested cubic volume by size class

<table>
<thead>
<tr>
<th>Harvest block</th>
<th>Fuel Logs</th>
<th>Total</th>
<th>Harvest block</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>8-9 d.b.h.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Production</td>
</tr>
</tbody>
</table>

Table 4—Machine utilization1 rates for the tree processor and chipper

| Area                  | Description | Species mix | Production
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Harvest block</td>
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<td></td>
<td>Processor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chipper</td>
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<tr>
<td></td>
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<td></td>
<td>Total</td>
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<tr>
<td></td>
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<td></td>
<td>Harvest block</td>
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<td>Processor</td>
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<td></td>
<td></td>
<td></td>
<td>Chipper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Table 5—Felling and skidding production

| Area                  | Description | Species mix | Production
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Harvest block</td>
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<td></td>
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<td>Chipper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Harvest block</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Processor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chipper</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Table 6—Production rates for feller bunchers (truck average)

| Area                  | Description | Species mix | Production
<table>
<thead>
<tr>
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</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machine</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tons/day2</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Shears</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

1Based on the time study samples expanded to an 8-hour shift, downtime included.
2Operational days = total time monitored except for the two skidders.

Several factors affected the International tree shear produc- tion. The processor was able to remove some kind of work and gained experience on the Arkansas Creek block. There was a decided improvement in the efficiency of the shear in the remaining three blocks. The spacing of leaves per tree was due to the factor with the operator having greater freedom in the clear-cut situation. Heavy branches, which lodged in adjacent tree crowns, affected handling of the sheared trees. The size of the trees cut had little effect on the shearing and bunching time, unless the stand was so thick that several small stems could be sheared at one time. Also, the International feller-buncher did not have an accumulator, so it had to lay down each tree as it was sheared.

The International shear eaily felled and bunches trees up to the capacity of the shear opening, i.e., 16 inches (45.7 cm) at the ground level. The Bobcat, on the other hand, had trouble with the taller trees over 14 inches (35.6 cm) d.b.h. The International shear seemed quite adequate for trees up to 18 inches, 45.7 cm. that age, on slopes up to 30 percent. Because of its small size, the Bobcat had trouble with large trees on slopes over 30 percent. Under favorable conditions (flat ground, small stems, etc.), the Bobcat was slightly more productive than the International machine. Because the Bobcat could travel fast with a comparison of speed, the operator made much larger bunches, which raised skidding production.

Skidding was done by two John Deere Model 640 rubber- banded skidders. One machine was equipped with a grapple, the other with standard chokers and winch. The machines performed quite different functions, so direct comparisons of pro- duction were not possible. Time study data, however, did contain information on hrs./skid, which provided a basis for comparison with respect to one of the factors that in- fluence production. Table 7 gives hour skid yields for the two skidders.

The table shows that the hour for the grapple machine was considerably less than that for the feller machine. Unskid time was more similar, though the grapple machine still re- quired less time.
Tree processing — Average production rates for the tree processor are given in table 8. Daily production rates are given in appendix B. In terms of tons of logs produced per day, the greatest average rate was attained at the Shreve Flat block, nearly 200 tons (182.5 tonnes/day) and the least at the Sunflower block, less than 90 tons (82 tonnes/day). The difference was probably due to the supply and size of saw log and chipper stems and their effect on the system balance. Based on total observed time of the tree processor, production in logs/minute ranged from 0.7 to 1.0, a difference of 144 logs in an 8-hour shift. Because of the extent and type of downtime included in the total time, these figures are difficult to compare. When all downtime is removed, however, only processing times remain and comparisons become more meaningful. Table 8 indicates that logs were processed considerably faster in the Sunflower and Cold Creek block than in the Arkansas-Shreve Flat block. These differences are largely because the larch and lodgepole pine can be processed faster than limber “bull pine” (ponderosa).

Initialy, some loggers said that sharing would cause massive defects through “butt shatter” or stem crushing. Such damage was less than one-half inch on most logs. Figure 7 shows butt ends of some shared trees. The tree butts that were subse-

To determine the tree processor’s hydraulic capacity, stem crushing might have been more severe if felled trees were being harvested. Some machine damage to logs can result if too much pressure is placed on the delimber knives of the tree processor. This pressure is controllable by the machine operator and should not be a problem with an experienced crew. Some “limb pull” defect was noted during the first part of the study. This defect was caused by a slow delimber knife speed that produced more of a pulling than a shearing action. A change in the high-speed sprocket drive on the delimber unit reduced the problem.

Figure 8 shows accumulated tops and limbs from the tree processor. An overaccumulation of this material plugs up the landing and requires the tree processor grapple to be used to feed the chipper.

Several occasions were noted to allow the chipper to catch up. It also happened on the other blocks when the tree processor grapple was used to separate logs and chipper stems material in the form of long, rather than maintaining a steady supply of tree lengths to the processor. These events were not recorded; however, a low production rate may be expected when the machine is part of a system that produces both logs and hog fuel. Appendix B presents daily tree processor productivity on both gross and net, overall basis. Utilization percentage is also shown. These daily figures reflect block differences, daily production problems, and the learning process during the study.

Of 99 loads of logs produced in the study, about 56 were measured and inspected under the Champion Timbers land log quality program. Two loads produced in the first harvest block showed total defect logs of 53 and 23 percent, respectively. After these two adverse reports were received, a concentrated effort was made to improve log quality by instructing the processor crew in species bucking specifications. The remaining log quality reports averaged 9.3 percent total defect. During the month of the study, log quality reports from the Champion Timbers land operations averaged 12 percent defect. Figure 6 shows the quality of delimbed logs.

Figure 8.—An accumulation of tops and limbs from the tree processor.

Whole-tree chipping — The average production rates in tons per day are given in table 8. A high of nearly 180 tons (164 tonnes) day was achieved in the Shreve Flat block and a low of about 120 tons (109 tonnes) day at the Shreve Flat block. Although the average utilization rates of the chipper are similar in all blocks (table 8), production rates varied considerably. See also appendix C for daily productivity utilization. Much of the variation was due to the kind of material chipped. In the Sunflower block and the Gold Creek block, many of the stems skidded to the landing were just under saw log size, were quite tall, and had few limbs (larch and lodgepole pines). This material produced more chips at a faster rate than the limbs and tops, which provided a greater proportion of the input of the Arkansas and Shreve Flat block.

Log recovery (476 M lb./ac.) was less than the preharvest crown. We attribute this to the difficulty of judging whether a small (marginally) tree would produce the minimum-sized log, especially from the cabs of the tree processor or whole-tree chipper. Apparently, the marginally trees looked smaller than they really were. For example, the Gold Creek block contained many marginal saw log stems. The cruise estimated a recovery of 41.5 M lb./ac. The actual recovery may be 7.5 M lb./ac. Identification of marginal saw log trees may or may not be a problem, depending on the relative values of marginal logs and whole-tree chips.

The chipper used in this study was set up to produce 3- to 1-inch chips. Hog fuel specifications, however, allow chip thickesses up to 2 inches (5.1 cm). The chipper operator suggested that if this machine were modified (a standard factory procedure) to produce 2-inch (5.1-cm) chips, chipping rate would be increased by 25 percent. Such an increase in chipping rates would increase the harvest value of the Sunflower block, where chipper capacity limited log production by the tree processor. Production of large chips could cause increased waste on the chip vans, especially on ramps or other areas that receive the full impact of blown chips.

Chip van — The chip vans used in this study were designed for highway use. The investigators had thought that offhighway use would require van reinforcement and that the trac-

ers should be geared the same as log trucks. An inquiry was made to the type of chip vans and tractors used in the Upper Peninsula of Michigan. In that region, special tractor gear-

ing or chip van reinforcement is not considered necessary. Ap-

arently, there is also little significant difference in gearing systems between highway and log trucks. Log trucks utilize a slightly lower gear ratio to help them start and move on steep grades or soft ground. Even in the Rocky Mountains, whole-tree chipping operations could probably be conducted on reasonably gentle terrain. Also with a whole-tree logging system, skidders would be available to assist trucks. Normally, log loading occurs after skidders have stopped working in an area.

During the study, chip vans were loaded by blowing chips through the rear doors. This method resulted in illegal loads due to poor weight distribution. A possible solution would be to load the top of the van, using a U-shaped spout that would distribute the chips more evenly. Top filling would also eliminate the unfavorable orientation of the chip vans on the landing (see fig. 2). For loadings of limited size without ade-

quate turning space, this modification would be essential. Figure 9 shows a landing that required much less area than the loadings shown in figure 4. Steep terrain limited the landing size.

The Haben Harvester representative said our production was low. He considered one load of log per hour a reasonable goal. At an average of 90 logs per load, this translates to 1.5 logs per minute. While the net production rate exceeded this figure in two blocks, the gross rate was only about half that value for the rest of the blocks. The chipping operation may have slowed down the log processor. This happened in the Sun-

Table 8.—Tree processor production rates.
Fuel consumption. — Fuel consumption data for the tree processor, chipper, and feller-buncher are shown in Table 10. These data are given because of the relative newness of this logging equipment.

Table 10. Fuel consumption rates

<table>
<thead>
<tr>
<th>Machine</th>
<th>Operating hours</th>
<th>Diesel fuel Consumption Rate (Gallons per Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hahn Harvester</td>
<td>111.6</td>
<td>439</td>
</tr>
<tr>
<td>Trelan chipper (Model DC-18)</td>
<td>111.8</td>
<td>884</td>
</tr>
<tr>
<td>International (Model 3966-8 feller-buncher)</td>
<td>142.7</td>
<td>387</td>
</tr>
<tr>
<td>Bobcat feller-buncher (Model 1075)</td>
<td>77</td>
<td>144</td>
</tr>
</tbody>
</table>

Evaluation as a Forest Management Tool

The potential of the system to accomplish various forest management tasks was evaluated in this study. Accomplishment is evaluated in the following sections.

Two tasks were: (1) feasibility of thinning stands and (2) clearing stands of small timber for regeneration on a commercial basis. Silvicultural method has little effect on the economics of this logging system. Profitability is more closely related to the balance between saw log and hog fuel production. In stands where the supply of hog fuel material was large, log production was reduced. Unfortunately, saw logs are the higher valued product, and idling of the tree processor increased costs and decreased profits.

Commercial thinning treatment is of little value if residual stand damage is high. When cutting and skidding were properly laid out, stand damage was minor and much less than conventional logging in the same stands. Where stand regeneration is desired, such as in characterizing and seed tree cutting, the system works very well since there are few standing trees to hinder the skidding operation. In some cases, a good job of scarification to encourage natural regeneration can be achieved in the process of skidding bunches of tree-length stems. The effectiveness of the scarification will depend on several factors. We observed that skidding of coarse limbed ponderosa pine was more effective than skidding of fine branched species. Also, soil conditions can be critical. Certainly, skidding on frozen or snow-covered soils will produce little scarification. The Arkan-
sas Creek block was harvested in August during a Douglas-fir seed year. Scarification was excellent. The following growing season was moist. Due to this fortunate combination of events, it appears that adequate natural regeneration has occurred. Figure 10 provides a comparison of before and after harvesting conditions on some of the harvest blocks. Slash treatment was not necessary on any of the blocks harvested.

It is a well-known fact that risk of insect attack is increased when partial cutting ponderosa pine stands, due to the improved breeding conditions for Ips bark beetles (Ips pini) in the accumulation of green slash. Whole-tree utilization definitely eliminates this problem. Only minor amounts of slash consist of fine branches that quickly dry and become unsuitable habitat for bark beetles are left in the stand.

Whole-tree utilization eliminates piling and burning. On the experimental logging blocks, one or two slash piles on landings were burned. These were made up of fine branches, soil, and stones. It was not considered worth the damage to chopper knives to process the material.

Air pollution due to slash burning is of concern in the study area. Air temperature inversions in the mountain valleys often limit the number of days when burning can be accomplished. Therefore, reduction in the total amount of material to be burned is a definite advantage for this harvest system because it reduces the cost of burning dependency on suitable weather and fuel conditions.

Stand access for current and future harvests was definitely improved by the use of feller-bunchers. The low stumps greatly reduced skidding problems. Also, smaller material that is normally pushed over during skidding was chipped for hog fuel. Elimination of the small trees also facilitated the skidding.

Visual impact of logged areas, especially along heavily traveled routes, is often a major concern. The appearance of all the blocks harvested by this system was esthetically satisfactory. This harvest system could probably be used in visually sensitive areas.
Figure 10.—Before (left) and after (right) logging views of study blocks.
SUMMARY AND RECOMMENDATIONS

The major reasons for this study were:

1. "Second-growth" and "small-log" harvesting costs are currently high; and new logging systems are urgently needed to handle this material efficiently and economically.

2. Methods to harvest biomass fuels and fiber efficiently and economically are also urgently needed.

3. Highly mechanized and specialized logging systems often prove to be necessary in managed stands. In the past, construction equipment with only minor modifications was sufficient to log large, high-value old growth.

The results of this study indicate that the harvest systems studied can produce a mix of hog fuel and logs at acceptable rates over a range of stand and site conditions under a variety of silvicultural prescriptions. Generally, the system is most productive (tons/man-hour) on gentle terrain in stands where the supply of sawable material is equal to or greater than the supply of chippable material. The results suggested that the system studied can operate profitably in stands where conventional systems would be uneconomical. This competitive advantage will increase as the value of small diameter material rises.

Recommendations for inclusion of this system in Champion Timberlands operation are based on:

1. Relative economics of this harvesting system compared to conventional methods.

2. The current need for wood as an alternative fuel source.

3. The place of this harvest system in overall logging programs.

4. Potential uses and abuses of the logging system.

We recommended that Champion Timberlands equip at least one crew with a tree processor, whole-tree chipper, two feller-bunchers, and two grapple skidders for a truly operational test of this harvest system. This crew should produce in excess of 15,000 units of hog fuel and 3 million board feet of logs in a 200-working-day year. Approximately 1,000 acres (404.7 ha) would be treated, yielding an average log volume of 4 M bd. ft./acre. The recommendation is assumed to be economically sound because the experimental harvest system produced logs at a favorable production rate relative to conventional logging. Also, hog fuel was produced at a cost about equal to current market prices. Within modest hauling distances, hog fuel can be produced more cheaply than hauling it from remote mill sites.

Because of terrain and weather in the Rocky Mountains, woods operations must be scheduled for areas that are suitable for summer-fall, winter, and spring logging conditions. Winter logging opportunities are confined to relatively low elevations and gentle slopes. The harvest system described in this report is limited to the same type of ground and might compete with conventional logging equipment for winter ground. This can be avoided by using the whole-tree system in stands where it has an advantage. For example, in the summer and fall, lodgepole and true fir could be clearcut on high elevation, gentle slopes. In the winter and spring, commercial thinning of ponderosa pine could be a specialty. The whole-tree harvest system has several advantages in such sites over conventional logging systems. Visually sensitive areas could also be a specialty of whole-tree logging.

Potential abuses include overthinning of stands that are being commercially thinned. Also winter game ranges could be temporarily stripped of storm shelter and forage during a commercial thinning. Perhaps whole-tree logging should be limited, as are clearcuts, to blocks under 40 acres unless large clearcuts are justified.

APPENDIX A

VOLUME AND LEGAL LOADS FOR STANDARD CHIP VAN AND TRACTOR COMBINATIONS

<table>
<thead>
<tr>
<th>Trailer type</th>
<th>Volume (cubic feet)</th>
<th>Montana legal gross weight (lb) including tractor</th>
<th>Estimated net weight (lb) of hog fuel</th>
<th>Approximate number of hog fuel units</th>
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<tbody>
<tr>
<td>40-foot</td>
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<tr>
<td>&quot;flat bottom&quot;</td>
<td>(73.6 m³)</td>
<td>78,600</td>
<td>49,700</td>
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<td>&quot;drop belly&quot;</td>
<td>(90.6 m³)</td>
<td>78,600</td>
<td>49,700</td>
<td>17.7</td>
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<tr>
<td>tandem axle</td>
<td>(99.0 m³)</td>
<td>79,400</td>
<td>50,100</td>
<td>17.9</td>
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<tr>
<td>45-foot</td>
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<tr>
<td>&quot;drop belly&quot;</td>
<td>(35.8 m³)</td>
<td>79,400</td>
<td>50,100</td>
<td>17.9</td>
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<tr>
<td>spread axle</td>
<td>(36.2 m³)</td>
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</tr>
<tr>
<td>Approximate number of hog fuel units</td>
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<td>17.7</td>
<td>17.7</td>
<td>17.9</td>
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</table>
## APPENDIX B

### TREE PROCESSOR PRODUCTIVITY

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Logs/day&lt;sup&gt;1&lt;/sup&gt;</th>
<th>M bd.ft./day&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Gross time</th>
<th>Net time</th>
<th>Gross time</th>
<th>Net time</th>
<th>Utilization</th>
<th>Percent</th>
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<tr>
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<td>211</td>
<td>312</td>
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<td>22.7</td>
<td>68</td>
<td></td>
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<td>456</td>
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<td>50</td>
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<td>Average</td>
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<td>311</td>
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<tr>
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<td>Sunflower Road</td>
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<td>662</td>
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<td>74</td>
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<tr>
<td>Average</td>
<td></td>
<td>393</td>
<td>538</td>
<td>33.3</td>
<td>42.3</td>
<td>72</td>
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</table>

<sup>1</sup>A day consists of 8 hours of production per shift.

## APPENDIX C

### WHOLE-TREE CHIPPER PRODUCTIVITY

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Average minutes per HF&lt;sup&gt;1&lt;/sup&gt; unit</th>
<th>Average minutes per load</th>
<th>Utilization</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gross</td>
<td>Net&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>08/04</td>
<td>Arkansas Creek</td>
<td>7.6</td>
<td>5.4</td>
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<tr>
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<td>Arkansas Creek</td>
<td>4.5</td>
<td>3.9</td>
<td>74.4</td>
</tr>
<tr>
<td>08/07</td>
<td>Arkansas Creek</td>
<td>3.3</td>
<td>3.1</td>
<td>55.0</td>
</tr>
<tr>
<td>Average</td>
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<td>4.1</td>
<td>78.7</td>
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<tr>
<td>08/11</td>
<td>Gold Creek</td>
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<td>3.7</td>
<td>76.8</td>
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<tr>
<td>08/12</td>
<td>Gold Creek</td>
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<td>3.4</td>
<td>78.0</td>
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<tr>
<td>08/14</td>
<td>Gold Creek</td>
<td>4.2</td>
<td>3.6</td>
<td>71.3</td>
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<td>Average</td>
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<td>4.4</td>
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<td>Sunflower Road</td>
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<td></td>
<td></td>
<td>Gross</td>
<td>Net&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
</tr>
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<td>3.4</td>
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<td>4.6</td>
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<td>Sheep Flats</td>
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<td>Sheep Flats</td>
<td>6.2</td>
<td>3.8</td>
<td>101.9</td>
</tr>
<tr>
<td>08/27</td>
<td>Sheep Flats</td>
<td>4.4</td>
<td>3.2</td>
<td>72.8</td>
</tr>
<tr>
<td>08/28</td>
<td>Sheep Flats</td>
<td>4.9</td>
<td>3.4</td>
<td>79.6</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>5.1</td>
<td>3.5</td>
<td>84.3</td>
</tr>
</tbody>
</table>

<sup>1</sup>HF = hog fuel
<sup>2</sup>Net time = gross time - delay time

Thinning operations on four different cutting blocks were monitored. The logging system consisted of feller-bunchers, grapple and choker skidders, and on the landing a whole-tree processor, chipper, and hydraulic loader. Variation in productivity among study areas was analyzed with respect to stand and site characteristics. Product alternatives and volumes were evaluated. Results indicated that (1) logs and chips can be produced at acceptable daily rates of 89 to 193 tons of logs and 119 to 178 tons of chips, (2) the proportions of saw logs and chipable material in the stand affect system productivity, and (3) complete utilization of slash provided additional benefits compatible with public and private forest management goals.

KEYWORDS: logging productivity, commercial thinning operations, product recovery

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

- Boise, Idaho (in cooperation with Idaho State University)
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with the University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)