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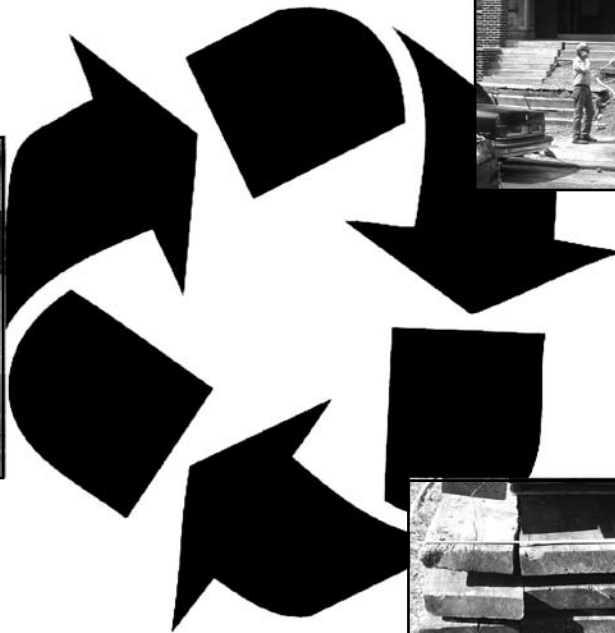
Forest  
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Paper  
FPL-RP-645



# Feasibility of Producing Value-Added Wood Products from Reclaimed Hemlock Lumber

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## Abstract

This study evaluated the feasibility of producing value-added wood products from hemlock lumber salvaged from building deconstruction. About 6,000 board feet of lumber, ranging in size from 3 in. by 8 in. to 3 in. by 12 in., was remilled into four products including log cabin siding, V-groove paneling, beadboard (wainscoting), and tongue and groove flooring. The general quality of the products produced was high and little loss was found after processing, although checks, ringshake, and face-nail holes were found in some pieces. The yield of value-added products was rather low (about 33%) and was constant over lumber size and product type. The authors believe yield could be increased with better on-site trimming.

Keywords: deconstruction, re-milling, salvage, lumber, wood, timber, reclaimed, recycling, reuse

### Conversion table

To convert from	To	Multiply by
Foot (ft)	Meter (m)	0.3048
Inch (in.)	Meter (m)	0.0254
Horsepower (hp)	Watt (W)	0.0746

July 2007

Janowiak, John J.; Falk, Robert H.; Kimmel, Jeffery D. 2007. Feasibility of producing value-added wood products from reclaimed hemlock lumber. Research Paper FPL-RP-645. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 13 p.

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## Acknowledgment

The investigators thank several individuals and companies for their efforts for and cooperation with the project. Our thanks to Mr. Jim Primdahl and the Institute for Local Self Reliance for helping supply the deconstructed hemlock lumber. We also express appreciation to Mr. Ed Plubell, owner of Quehanna Millwork (Frenchville, Pennsylvania), for his full cooperation in processing the reclaimed hemlock feedstock into the various millwork patterns and Wizard Industries (Van Nuys, California) for their support to the experimental study.

## Contents

	<i>Page</i>
Executive Summary .....	<i>i</i>
Introduction .....	1
Description of Reclaimed Hemlock Lumber .....	1
Material Delivery and Initial Inspection .....	1
Detailed Assessment .....	2
Millwork Patterns .....	3
Project Study Tasks .....	3
Lumber Piece Identification .....	3
Size Classification .....	4
Feedstock Preparation .....	4
Millwork Production .....	7
Millwork Quality Assessment .....	7
Quantitative Results .....	8
Millwork Recovery .....	8
Product Valuation .....	9
Grade Quality Observations .....	9
Visual Demonstrations .....	12
Conclusions and Recommendations .....	12

## Executive Summary

The objective of this study was to evaluate the feasibility of producing value-added wood products from hemlock lumber salvaged from building deconstruction. About 6,000 board feet of lumber was purchased from a deconstruction contractor and delivered to Pennsylvania State University for evaluation. The initial tally (piece count) of heavy dimensional lumber included the following (estimated size and typical length): 21 pieces (nominal 3 in. by 12 in.) at 19.0 ft; 29 pieces (3 by 12) at 15.5 ft; 76 pieces (3 by 9) at 15.6 ft; and 33 pieces (3 by 8) at 16.0 ft (159 total pieces of reclaimed joist lumber). When delivered, the lumber varied in condition with decay, ring shake, and end splits evident in many pieces. Because the lumber was rough sawn, the thickness varied, increasing the work in pre-processing the material for re-milling.

Four products were targeted for re-milling based on the species of wood and the sizes available: log cabin siding, V-groove paneling, beadboard ceiling (or wainscoting), and tongue and groove flooring. Preprocessing of the material included cutting out defects and decay and removing metal missed in the on-site denailing. After this preprocessing, only about a third of the lumber remained for re-milling. The lumber was shipped to Quenhanna mills (Frenchville, Pennsylvania) and various milled products were produced. In general, the quality of the products was high and little loss was found after processing, although checks, ringshake, and face-nail holes were found in some pieces. The yield of value-added products was about 33% and was constant over lumber size and product type. The value of the products produced was about U.S. \$2,800. To increase yield and reduce costs, we recommend purchasing only metal-free lumber and trimming more on the jobsite. The authors believe that costs could be further reduced in a re-milling operation with a constant stream of material sized to achieve economy of scale.



# Feasibility of Producing Value-Added Wood Products from Reclaimed Hemlock Lumber

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## Introduction

Thousands of buildings are torn down every year in the United States, and many have begun to recognize value in materials currently discarded. Interest is growing in reusing lumber and timber salvaged from building deconstruction. Often the lumber available from deconstruction is the last of a once vast old-growth forest resource and is unavailable from any other source.

Many cities offer an opportunity to salvage lumber and other building materials from buildings slated for demolition. In the city of Philadelphia, the Neighborhood Transformation Initiative (NTI) is investigating a strategy for incorporating deconstruction as a component of ongoing building demolition.

The NTI is a comprehensive 5-year plan that addresses urban blight through a multifaceted program to preserve and build healthy communities throughout the city. One important goal of the program is the demolition of 10,000 dangerous and structurally unsound housing units. The NTI recognizes value that still exists in the condemned buildings and is exploring ways to recover salvageable materials cost effectively.

The NTI demolition project offers unique, large-scale opportunities for landfill avoidance and economic development by reclaiming building materials using mechanized building-dismantling techniques. This dense urban setting combines site constraints and high labor rates with the possibility of obtaining high-value reclaimed lumber in roofs and floors in thousands of buildings slated for demolition in one concentrated geographic area. These factors in turn produce great potential for economies of scale.

During summer 2003, two Philadelphia row houses were deconstructed as part of a pilot project to investigate an alternative to demolition and landfill. About 6,000 board feet of hemlock lumber, in the form of 3 by 12s, 3 by 9s, 3 by 8s, and 3 by 7s was salvaged during this process. These measurements represent inches of sectional rough-sawn cross-dimensional lumber, hereafter referred to as 3 by 12, 3 by 9, 3 by 8, 3 by 7, etc.

The USDA Forest Products Laboratory (FPL) purchased this lumber, and through a cooperative research project with the

Wood Products Program at Pennsylvania State University (PSU) evaluated the feasibility of developing value-added products from this lumber. This report is a summary of that effort.

## Description of Reclaimed Hemlock Lumber

### Material Delivery and Initial Inspection

Hemlock from the Philadelphia deconstruction project was delivered to a PSU facility operated by the College of Agricultural Sciences. This facility had the space for sorting and an on-site portable bandmill for re-sawing the hemlock into suitable feedstock for processing into millwork.

Materials delivered included heavy dimensional joists as large as 3 by 12 and lighter stud dimension lumber as small as 2 by 3. The joist lumber was representative of wood-framing members found in older rowhouses in Philadelphia. A tally was made of the lumber delivered with an initial assessment of physical condition. Shortly after delivery, a more detailed inspection was conducted in conjunction with sorting of study materials into groupings of similar nominal-size classifications.

Sorting provided the opportunity to organize lumber, preview the condition of individual pieces, and inspect it for metal or other embedded objects. This initial look at the lumber indicated that much of the smaller dimension stud material was either twisted or exhibited other defects that made it unsuitable for producing quality millwork.

Because of this, we decided to focus only on the heavy dimension (3-in. nominal) pieces. The initial tally (piece count) of heavy dimensional lumber follows: 21 pieces (3 by 12) at 19.0 ft; 29 pieces (3 by 12) at 15.5 ft; 76 pieces (3 by 9) at 15.6 ft; and 33 pieces (3 by 7 or 3 by 8) at 16.0 ft (159 pieces total).

Unfortunately, the lumber had been stored outside for several weeks without protection from the weather prior to arriving at PSU. The surface moisture content was clearly elevated in many of the pieces. Measurements with a Delmhorst RXM-1 electrical-resistance moisture meter (Delmhorst Instrument Company, Towaca, New Jersey) indicated that moisture contents as high as fiber saturation (>30%



**Figure 1—Lumber with stickers placed between the rows and sorted into stacks to allow surface moisture drying.**



**Figure 2—The lumber was covered with tarps open at the ends to allow air drying while preventing further wetting from rain.**

moisture content (MC)) existed up to 3/8 in. deep in some of the pieces. However, readings at a 1-1/8 in.-probe depth indicated fairly consistent 10% to 12% MC. This level of moisture is generally expected for framing members from deconstructed buildings and is acceptable for machine processing of millwork.

The lumber was organized into convenient stacks sorted by width and length. Stickers were placed between the rows of stacked lumber to provide air circulation and speed drying of excess surface moisture (Fig. 1). Tarps were used to cover the lumber and prevent further wetting; they were left open at the ends to provide air movement for drying (Fig. 2).

### Detailed Assessment

Visual inspections during unloading and later sorting indicated the existing physical condition of the lumber and the



**Figure 3—Exposed cut shank nails marked for removal. Also shown is a surface check that may go deep into the lumber piece, affecting potential wood product yield.**

degree to which it had been cleaned of nails. Inspection revealed that the de-nailing was only partially completed with about 90% of members being fully free of nails (Fig. 3). More importantly, we found many pieces with broken-off nail shanks that were difficult to see. An inexpensive but effective hand-held metal detector (Wizard Industries, Inc., Glendale, California) was used to locate the metal. By the time the lumber reached the millwork facility, it had been scanned with the detector several times. Assuring that no metal remains in the wood is critical for avoiding possible moulder damage and preventing the cost of sharpening or replacing profile knives.

The visual inspection also revealed various degrees of surface checking related to in-service drying. Three pieces were so heavily and deeply checked that they were rejected outright as unsuitable for processing. Instead of processing these pieces into millwork, we used them as test pieces to set up the bandmill. All others were lightly checked and allowed for processing. Other surface conditions included the presence of paint coatings and what appeared to be either cement or plaster (Fig. 4). These materials can quickly dull moulder knives and must be removed to maintain knife sharpness and finished surface quality.

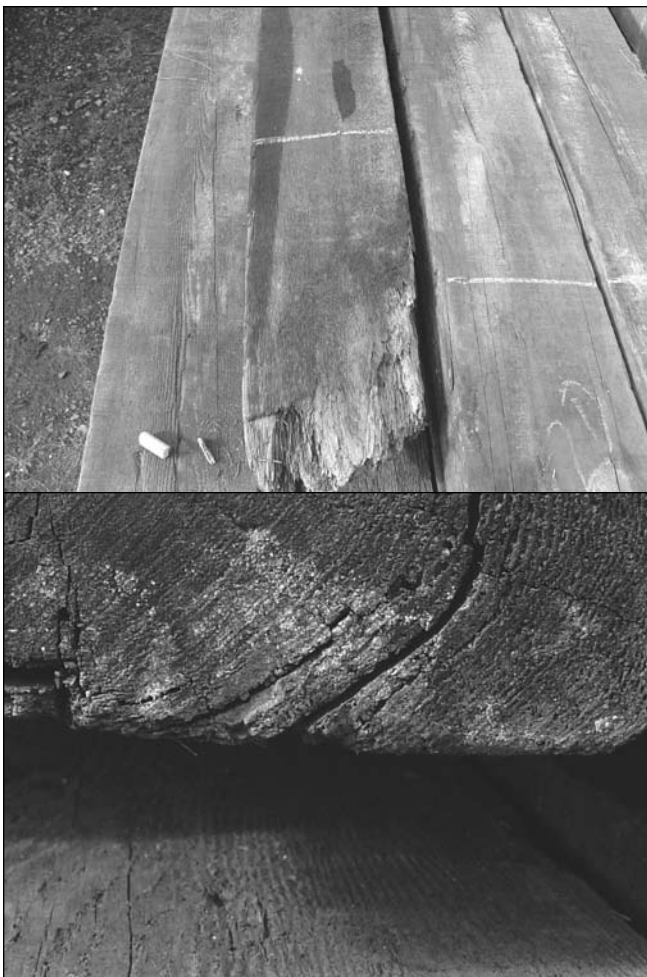
Decay, shake, and end splits were also evident on a number of the lumber pieces. In some cases, advanced decay extended 1 to 2 ft on one or both ends of the 3 by 12 lumber. This likely was due to water from leaky roofs wetting the ends of the roof-support joists (Fig. 5).

The lumber was all rough sawn without prior surfacing to a standard thickness. As a result, thickness and width varied 1/4 in. or more (Fig. 6).

The PSU Forest Resources Laboratory staff examined samples of the lumber with a microscope and confirmed that the lumber was eastern hemlock (*Tsuga canadensis*).



**Figure 4**—Some lumber was clean, whereas other pieces had been painted or had surface contamination of cement or plaster.



**Figure 5**—The decayed ends of the 3 by 12 joists were marked with a line for cutting (top). Ring shake, or separation between growth rings, is common in hemlock and was found in many pieces (bottom).



**Figure 6**—The thickness of the lumber studied varied because it was originally installed rough sawn.

### Millwork Patterns

On the basis of the visual assessment described above, a number of millwork product options were investigated. Discussion between the PSU and FPL investigators concluded that four millwork patterns would be logical candidates for further investigation. These patterns included the following:

1. Tongue and groove (T&G) square edge-matched flooring, 3/4 in. thick
2. V-groove T&G wall paneling, 3/4 in. thick
3. Beaded T&G ceiling or cut-to-length T&G wainscot, either 3/4 in. or 3/8 in. thick
4. Radius log cabin siding, 1-3/4 in. thick

These four millwork patterns were chosen to maximize yield, and we considered available lumber thickness, lumber-length distribution, and prevalence of defects. Each would be produced at Quenhanna Mills, a custom wood products mill in Frenchville, Pennsylvania, on a 4-head moulder, a commonly used wood profiling machine.

We decided relatively early to abandon the idea of producing a 3/8-in.-thick beaded panel. We thought that by producing a thinner paneling, the overall yield of paneling (on a square footage basis) would increase. However, this expected increase was not possible because the thickness of most lumber pieces (~2-7/16 in.) did not provide enough material for added sawline cuts while assuring that the surface of the final product remained check free.

### Project Study Tasks

#### Lumber Piece Identification

During initial sorting, each full-length piece of lumber was assigned an identification number. This number was marked at two locations to assure that the piece could be tracked through cut-to-length processing, re-sawing, and final profile processing (Fig. 7).



**Figure 7—An identification number for each piece was used to track material yields.**



**Figure 8—Measurement of lumber width (top) and length (bottom).**

## Size Classification

An additional task during sorting was measurement and classification of actual width and length. Width was measured at the ends of each piece at two locations and averaged. Thickness was measured at mid-length. Measurements for width and thickness were rounded off to the nearest 1/8 in. while length was rounded to the nearest 1/4 in. (Fig. 8).

Data generated from size classification and the piece counts allowed us to calculate total lineal footage and computed board foot volumes of lumber (Table 1). Computed board foot values were rounded down to the nearest unit measure. Recall that one board foot is a lumber piece 1 by 12 by 12 in.

Table 1 shows the average thickness ( $t$ ), width ( $w$ ), and length ( $l$ ) within each size classification. The range of thickness and width dimensions observed (Table 1) is not ideal, as enough variation in dimension existed that many of the pieces required re-sawing to unify sizes.

## Feedstock Preparation

To prepare each lumber piece for profiling in the moulder, uniform-sized “feedstock” needed to be produced. This involved cross cutting to eliminate rotted ends and larger defects along the length, edge-sawing to unify width and eliminate edge defects and nail holes, and surface-planing to clean the faces of the lumber of any contaminant (paint, plaster) that might dull the moulder blades.

Quehanna provided guidance on the most appropriate feedstock dimensions for their moulders. For log cabin siding, the target thickness was 2-1/8 in. ( $\pm 1/16$  in.) and a width of 8-1/16 in. For paneling and flooring, target thickness was 1-1/8 in. with target widths ranging from 4-1/16 in. to 6-1/16 in.

## Cut-to-Length Processing

A simple system of removing defects and cutting to length was set up using a cross-cut saw. A fork lift was used to transport the sorted lumber packs and minimize strenuous lifting of heavy dimension lumber. A sliding compound miter was necessary to cross cut the full 12-in.-width lumber. Figure 9 shows this simple arrangement for cutting to length.

Exposed nails were removed prior to cross cutting using hammers, crowbars, and pliers. In many cases, the exposed head of the nail broke off during pulling (or had previously rusted off), which left the nail shank visually undetectable and embedded in the wood (Fig. 9). For this reason, we used a hand-held metal detector to locate nails and other embedded metal hardware. We found we needed to periodically calibrate and adjust detector sensitivity. It was very important to detect and remove this metal before molding the wood to final profile. While a cross-cut circular saw with carbide blades can tolerate some abuse from hitting a nail,



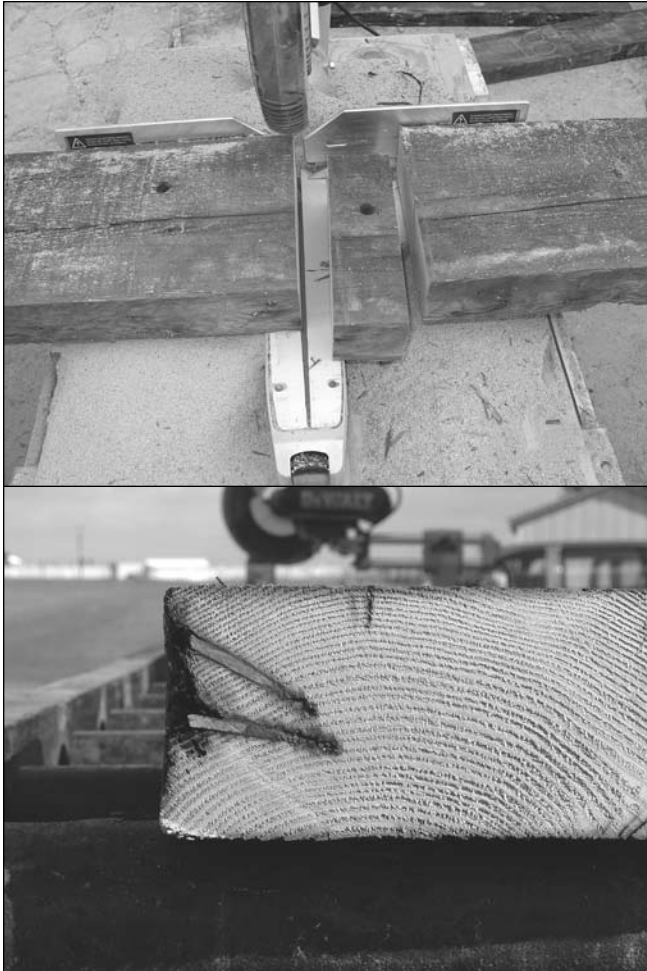
**Table 1. Detailed inventory of rough-sawn hemlock lumber**

Nominal dimension (in.)	Measured dimension <sup>a</sup>			Piece count	Lineal (ft)	Volume (bf) <sup>b</sup>
	Thickness, <i>t</i> (in.)	Width, <i>w</i> (in.)	Length, <i>l</i> (ft. in.)			
3 by 12	2-7/16 (2-5/8 < <i>t</i> < 3)	11-3/4 (11-1/8 < <i>w</i> < 12)	17 4-3/4 (10-10 < <i>l</i> < 19 7-3/4)	50	871	2,526
3 by 9	2-7/8 (2-3/4 < <i>t</i> < 3-1/8)	8-3/4 (8-3/8 < <i>w</i> < 9-1/4)	15 5-1/4 (13 2-3/4 < <i>l</i> < 15 9-3/4)	73	1,128	2,446
3 by 8	2-13/16 (2-3/4 < <i>t</i> < 3)	7-3/4 (7-1/2 < <i>w</i> < 8-3/4)	18 9-1/4 (17 5-1/4 < <i>l</i> < 19 6-1/4)	11	207	400
3 by 7	2-7/8 (2-5/8 < <i>t</i> < 3-1/8)	6-13/16 (6-1/2 < <i>w</i> < 7)	15 5-1/4 (14 1-3/4 < <i>l</i> < 15 9)	22 <sup>c</sup>	340	572
Total						5,944

<sup>a</sup> Average and range given.

<sup>b</sup> Board footage (bf) values shown are calculated from the nominal dimension and length rounded down to nearest whole foot.

<sup>c</sup> Three pieces of 3 by 7 rejected for conversion to millwork and used to set up the bandmill for sawing of rough lumber.



**Figure 9—Cross-cutting to remove decay and defects (top); broken off nails in lumber (bottom).**



**Figure 10—Waste generated through cross-cutting out defect.**

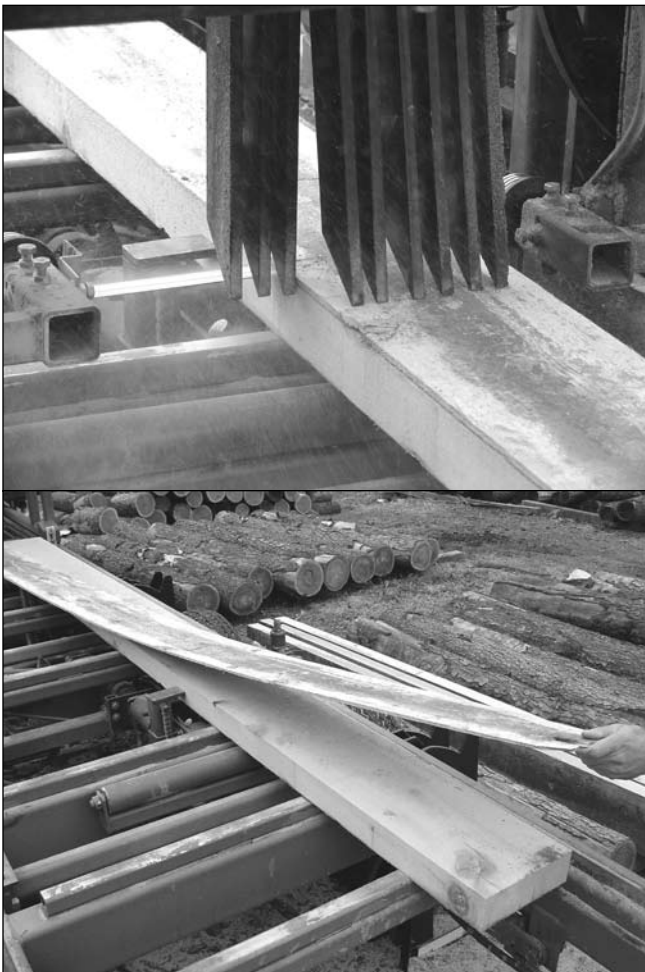
damage to moulder knives from undetected metal or some other foreign object can get very expensive.

After cross cutting all lumber pieces to eliminate defects or embedded objects, each piece was measured again to track losses of material. Sectional cuts of usable material were marked to retain the original code identification number and then restacked into packs (Fig. 10). This task resulted in a substantial volume loss, increased the total piece count, and associated handling and labor. Losses varied widely from piece to piece.

In addition to decay removal, various pieces were severely damaged mechanically or had other embedded objects not easily removed without cross-cut processing.



**Figure 11—Edge sawing of 3 by 12 reclaimed hemlock. A 1-3/4-in.-depth cut was used to remove embedded edge nails.**



**Figure 12—Rough hemlock being re-sawn to uniform thickness.**

### Edge-Sawing

After cross-cutting out defects, the pieces were re-sawn to the target feedstock widths (Fig. 11). Edge-sawing involved first a lighter 0.5- to 1.0-in. depth of cut opposite the heavy-nailed joist-flange edge. This first cut produced one straight edge on the piece. This left a sufficient amount of material for a deeper second cut on the opposite edge to eliminate existing embedded nails, nail holes left from removing nails, and the surrounding metallic discoloration resulting from nail corrosion. Figure 12 shows this two-stage sawing on several pieces of lumber secured in the carriage of the 30-hp diesel-powered portable Timber Harvester band mill used in this study.

We determined that a 1-1/2-in. cut was the minimum needed to remove most of the nail penetration holes. A heavier cut of 1-3/4 in. to 2 in. was needed to remove ferrous metal stains. To speed the re-sawing operation, several pieces were edged at the same time. Four pieces were determined to be the practical limit to avoid sawblade binding and allow a reasonable sawing speed. A thin-kerf (0.053 in.) sawblade was also used to minimize waste.

Most of the narrower lumber pieces (3 by 9, 3 by 8) were edge-ripped to a 6-1/16-in. feedstock width to produce either V-groove paneling or beaded paneling (wainscot). Because of width variation, some of the 3 by 8 and 3 by 9 pieces were wide enough to produce a 6-1/2-in. feedstock for processing into the tongue and groove square edge flooring. The smaller size 3 by 7 lumber was primarily sawn to a 5-1/16-in. feedstock width, although a narrower 4-1/16-in. feedstock was also produced for processing into a narrower flooring pattern. The moulder equipment at Quehanna is designed to machine flooring of variable widths from over 6 in. wide down to 3-1/8 in. (face coverage) in 1/2-in. increments.

### Surfacing

Following edging, each piece was re-sawn using the portable band mill to remove paint and other surface contamination and to produce pieces of uniform thickness. Because of so much variation in thickness, a planer would require multiple passes. Re-sawing to a uniform thickness proved to be a more efficient operation (Fig. 12).

Because the original thickness of the rough lumber was nearly 3 in. thick, it was possible to produce two 1-1/8-in.-thick pieces of feedstock for paneling and flooring, though this required an extra re-sawing step. Not all pieces could be processed into two full-length pieces of feedstock because of defects such as notching (Fig. 13). This type of defect did not typically restrict processing of feedstock acceptable for the intended log cabin siding pattern.

Table 2 summarizes the target dimensions and yields of feedstock for the various patterns of product to be produced. It is apparent from this table that the greatest yield, in terms of board footage, is the log cabin siding. However, in terms

**Table 2. Yield of feedstock (lineal footage and board foot measure)**

Pattern description	Target feedstock dimensions			Actual yield				
	Thickness (in.)	Width (in.)	Minimum length (ft)	Final width (in.)	Piece count	Lineal (ft)	Volume (bf)	Coverage area (ft <sup>2</sup> )
Log cabin siding	2-1/8	8-1/16	8 <sup>a</sup>	7	64	505	668	295
V-groove paneling	1-1/8	6-1/16	6	5-1/2	45	340	170	156
Beaded ceiling	1-1/8	5-1/16	6	4-1/2	39	294	123	110
Flooring	1-1/8	4-1/16	2	3-1/8	73	354	118	92
	1-1/8	5-1/16	2	4-1/8	107	509	212	175
	1-1/8	5-1/16	2	4-1/2	39	294	123	110
	1-1/8	6-1/2	2	5-5/8	58	250	135	117
			Subtotal flooring		238	1,113	465	384

<sup>a</sup> A few log cabin siding pieces were slightly less than 8 ft long.

of square footage the final product will cover, the beaded ceiling and flooring have the highest yields. This is because the log cabin siding is thicker and requires more raw material per square foot of final product.

**Millwork Production**

All the feedstock produced was transported to Quehanna Millwork, Inc., for moulding into the final millwork patterns. To assure proper moulding (in-feed to cutterhead alignment control) and meet product dimension norms, a minimum length was established for each product length (Table 2). The log cabin siding feedstock was mostly 8 ft long with few pieces slightly less, the beaded ceiling and V-groove panel at least 6 ft long, and the flooring feedstock at least 2 ft long.

All moulding was run at speeds resulting in not less than 12 knife cuts per inch. This speed would produce finish-ready millwork requiring only a light surface sanding before application of a polyurethane or other clear finish treatment (Fig. 14).

Because the flooring moulder could accommodate various widths of feedstock, each piece was individually examined for defects immediately before moulding to determine the widest flooring piece that could be produced from it. Also, each piece was closely examined during processing to determine the appropriate amount of material to be removed from the top or bottom face to eliminate (or at least minimize) surface checks in the final product. Some pieces had checks so deep on both faces that further processing would have been futile (Fig. 15).

**Millwork Quality Assessment**

Following each production run, the millwork was brought back to the PSU Forest Resources Laboratory to conduct an assessment of finish quality. Dressed surfaces for all

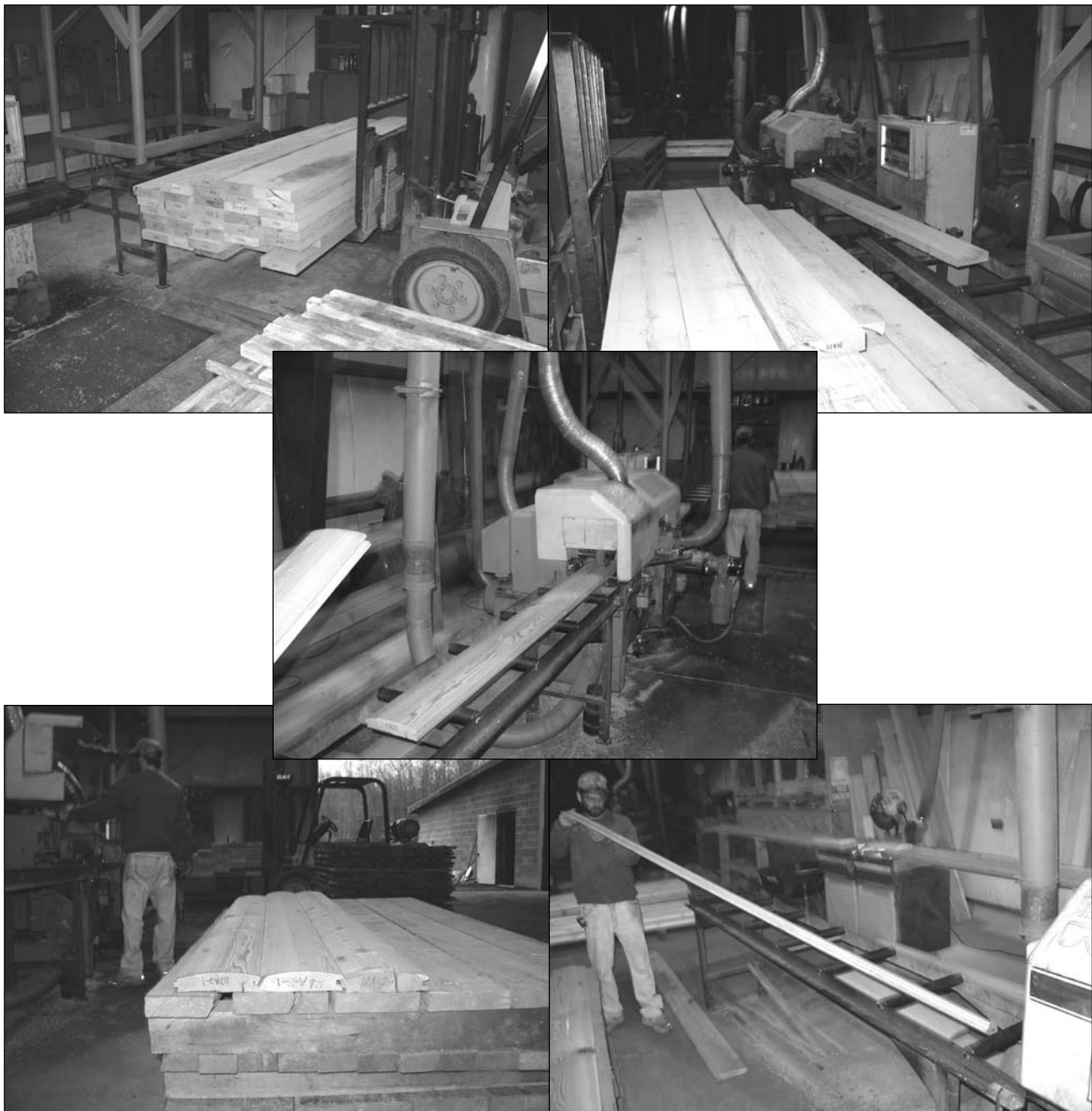


**Figure 13—Flaw limiting recovery of a matched pair of feedstock pieces.**

patterns processed were quite good, and only a few pieces had enough torn or chipped grain to adversely affect the visual appearance or grade quality. Raised (fuzzy) grain sometimes associated with high wood-moisture levels was observed but was mostly sporadic and not considered significant. A few pieces had some localized sap-staining from fungi apparently related to the original air-drying of lumber.

Shallow residual surface checks, ring shake, face-nail holes, and metallic stain appeared to be the most prevalent defects found in the finished product. Some pieces also contained heart center/pith (from those pieces of feedstock originally from box-heart pieces of lumber). These defects found after processing are shown in Figure 16.

Figure 17 shows a closer view of the three widths of flooring produced, whereas Figure 18 shows the V-groove paneling and beaded ceiling paneling produced. Note the



**Figure 14—Converting the 8-1/8 in.-wide log cabin feedstock into 7-in. face-coverage log cabin siding.**

different grades. The highest visual grade, C and better, is indicated as well as a lower D-grade, which allows more knots and other defects.

## Quantitative Results

### Millwork Recovery

Table 3 gives the recovery percentage of processed millwork relative to the original source (size classification) and initial board-foot volume of hemlock. This table also summarizes loss of material with cut-to-length processing (end-trimming) to remove decay, end-splits, shake, and other defects.

On average and across all size classes of lumber, about 15% volume was lost in the initial cut-to-length processing. Another 51% of the lumber volume was lost in preparing the material to feed the moulder. This volume reduction can be traced back the edge sawing, surfacing, and re-sawing operations. For example, resizing the original 3 by 12 pieces down to 8-1/16 in. for log cabin feedstock represents a 31% loss of material. Resurfacing the original thickness to the target 2-1/8 in. thickness dimension represents a 12.8% material loss. Finally, the three sawline cuts in the sawing solution equates to 0.156 in. kerf waste or another 6.4% reduction in lost material volume. In the end, about

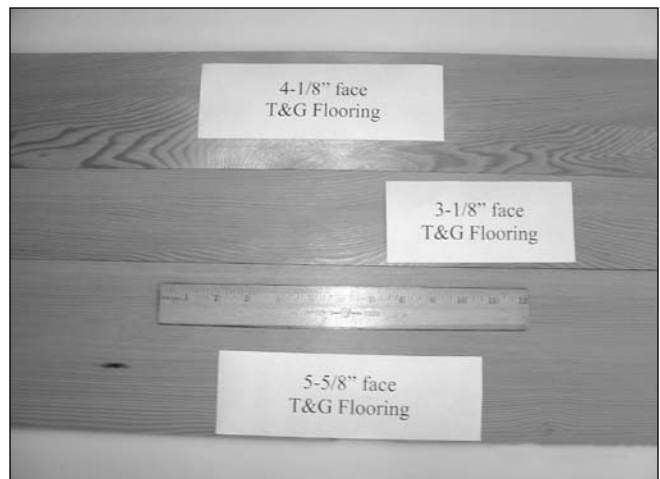


**Figure 15—Typical defects found after moulding the lumber. Flooring pattern shown.**

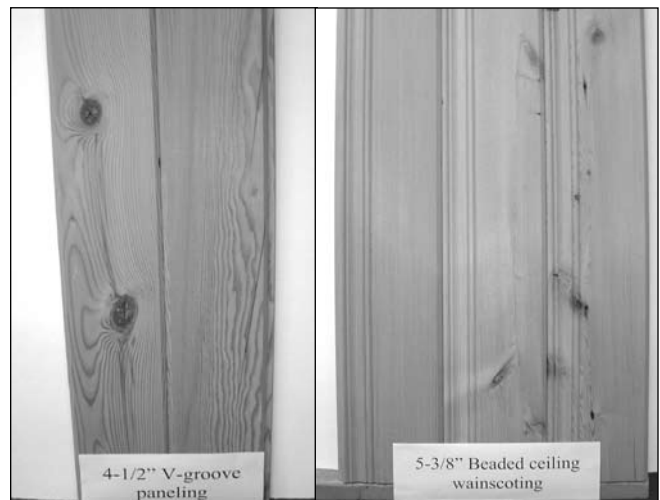
66% of the original volume of lumber supplied was lost as waste to produce the final finished products.

**Product Valuation**

Despite the rather large material losses, reprocessing the lumber increased its value. Table 4 presents a pricing



**Figure 16—Close-up view of three widths of flooring produced.**



**Figure 17—Grade quality for V-groove paneling (left) and beaded ceiling (right) with common allowable defects.**

valuation for the recycled hemlock as merchantable millwork compared with fair market value if it were sold as reclaimed lumber.

Remanufacture of salvaged lumber into finished millwork increased the value of reclaimed hemlock from \$1,774 to an estimated market value of \$2,829. The difference equals a 59.5% increase in value; however, this does not account for labor and equipment costs. Profitability to convert this type of material into millwork will be strongly influenced by prevailing labor rates, capitol investment for equipment, and local markets.

**Grade Quality Observations**

In addition to evaluating appearance quality, all moulding was evaluated according to millwork grading rules. Traditionally, eastern hemlock was not used to produce millwork products, and the grading rules used to grade this

**Table 3. Board footage volumes (bold print) of value-added products by nominal size class with associated recovery percentages (*italics*) based on initial volume**

	Before moulding		After moulding							
	Initial sort volume	Adjusted volume (after cut to length)	Log cabin siding 7 in. <sup>a</sup>	V-Groove paneling (in.) 4-1/2 <sup>b</sup>		Beaded ceiling 5-1/2 <sup>c</sup>	T & G flooring 5-3/8 in. <sup>c</sup>			Processed pattern totals
			–	–	–	3-1/8 in. <sup>d</sup>	4-1/8 in. <sup>b</sup>	5-5/8 in. <sup>e</sup>		
3 by 12	<b>2,526</b>	<b>2,238</b>	<b>673</b>				<b>78</b>	<b>75</b>	<b>32</b>	<b>859</b>
		<i>88.6</i>	<i>26.7</i>				<i>3.1</i>	<i>3.0</i>	<i>1.3</i>	<i>34.1</i>
				–	<b>58</b>	<b>548</b>				
3 by 9	2,414	1,964	–		2.4	22.7	<b>12</b>	<b>76</b>	<b>98</b>	<b>794</b>
		<i>81.4</i>					<i>0.5</i>	<i>3.2</i>	<i>4.1</i>	<i>32.9</i>
				–	<b>111</b>	<b>3</b>				
3 by 8	<b>400</b>	<b>318</b>	–		27.9	0.8	<b>2</b>	<b>17</b>	<b>5</b>	<b>139</b>
		<i>79.5</i>					<i>0.4</i>	<i>4.4</i>	<i>1.3</i>	<i>34.8</i>
					<b>122</b>	–				
3 by 7	<b>572</b>	<b>483</b>	–	21.4			<b>25</b>	<b>43</b>	–	<b>191</b>
		<i>84.4</i>					<i>4.4</i>	<i>7.6</i>		<i>33.4</i>
Total	<b>5,912</b>	<b>5,003</b>	<b>673</b>	<b>122</b>	<b>169</b>	<b>551</b>	<b>117</b>	<b>211</b>	<b>135</b>	<b>1,978</b>
Average		<i>84.6</i>								<i>33.5</i>

<sup>a</sup> 2 by 8 volume basis for calculation of board foot values.

<sup>b</sup> 1 by 5 volume basis.

<sup>c</sup> 1 by 6 volume basis.

<sup>d</sup> 1 by 4 volume basis.

<sup>e</sup> 1 by 6.5 volume basis.

**Table 4. Summary product valuation of the processed millwork<sup>a</sup> versus the value of the as-received reclaimed hemlock lumber**

Nominal dimension	Initial volume (bf)	Initial value <sup>b</sup> (\$)	End-trimmed footage (lineal ft)	Total coverage (ft <sup>2</sup> )	Assessed product value <sup>c,d</sup> (\$)	Value added (\$)
3 by 12	2,526	757.80	746	–	1,327.88	570.08
3 by 9						
3 by 8	3,386	1,015.80	–	994	1,500.94	485.14
3 by 7						
Totals	5,912	1,773.60	–	–	2,828.82	1,055.22

<sup>a</sup> Prices for value-added millwork similar to those produced in this study for white pine products listed online: [www.cedar-log-homes.com](http://www.cedar-log-homes.com).

<sup>b</sup> Valuation based on purchase price of \$0.30 per board foot (fair market value).

<sup>c</sup> Valuation based on end-trimmed 3 by 12 materials with major defect removal for generation of 2 by 8 feedstock to produce log cabin siding valued at \$1.79 per lineal foot.

<sup>d</sup> Valuation based on total square foot coverage of patterns generated from 3 by 9, 3 by 8, and 3 by 7 materials collectively valued at \$1.51 per square foot.

**Table 5. Summary of grade breakdown for log cabin siding, V-groove paneling, and flooring patterns**

Millwork product	Face coverage (in.)	Grade	Piece count	Total lineal (ft)	Limiting defect or distinguishing visual characteristic <sup>a</sup> (frequency)	Pieces upgraded (lineal feet lost)
Log cabin siding	7	C	3	24	clear (2), checks (1)	–
		D	7	56	knots (2), checks (3), holes (2)	2 C (2)
		E	54	421	knots (40), holes (13), split (1)	7 D (10)
		<b>Total</b>	<b>64</b>	<b>501</b>	one piece below E grade	
V-groove paneling	4 1/2	C	8	61	clear (4), knots (2), nail holes (2)	–
		D	11	84	knots (5), checks (2), holes (2), splits (1), nail holes (1)	1 C (2)
		E	20	149	knots (20)	3 C (6)
		<b>Total</b>	<b>39</b>	<b>294</b>		
	5 1/2	C	1	6	knots (1)	–
		D	14	108	knots (12), holes (2)	–
		E	30	226	knots (19), holes (11)	1 C (2)
		<b>Total</b>	<b>45</b>	<b>340</b>		
	3 1/8	C	10	46' 8"	clear (5), knots (4), checks (1)	–
		D	31	163' 5"	knots (15), holes (8), checks (8)	6 C (8)
		E	32	179' 4"	knots (23), holes (9)	14 C (24), 2 D (4)
		<b>Total</b>	<b>73</b>	<b>389</b>		
Tongue and groove flooring <sup>b</sup>	4 1/8	C	25	125' 4"	clear (23), knots (2)	–
		D	35	195' 8"	knots (15), holes (8), checks (11), split (1)	7 C (9)
		E	47	229'	knots (39), holes (7), split (1)	7 C (11), 1 D (1)
		<b>Total</b>	<b>107</b>	<b>550</b>		
	5 5/8	C	9	37' 9"	all clear	–
		D	19	88' 8"	knots (6), holes (7), checks (6)	1 C (1)
		E	30	155'	knots (22), holes (8)	2 D (4)
		<b>Total</b>	<b>58</b>	<b>281</b>		

<sup>a</sup> West Coast Lumber Inspection Bureau standard grading rules for ceiling and siding and flooring with residual nail holes and associated metallic stain disregarded as defect unless so noted as distinguishing characteristic.

<sup>b</sup> Lineal footage measured to the nearest inch.

species (Northeastern Lumber Manufacturers Association or Northern Softwood Lumber Bureau) only certify its use as structural lumber. For this reason, we evaluated the moulding using West Coast Lumber Inspection Bureau (WCLIB) grade rules. The WCLIB softwood rules cover western hemlock, a closely related species, and includes criteria applicable to the moulding patterns produced in this study. Table 5 summarizes the results of this grading and includes the frequency of each particular grade limiting defects along with the numbers of residual nail holes observed. All holes (Fig. 4) were treated as unsound knots as permitted under WCLIB rules. Nail holes or metallic discoloration were not directly referenced in millwork rules and were therefore disregarded as a defect.

The C-grade designation denotes the highest grade of millwork. Grades D and E are lower grades and allow larger

knots, end-splits, and other defects. For example C-grade flooring is generally restricted to only two small, sound, tight knots (or equivalent defect) with the majority of surface being clear. Recovery of C-grade log cabin siding, V-groove paneling, and flooring were 4.8%, 10.6%, and 17.2%, respectively. Recovery of lower D-grade millwork for log cabin siding was 11.1%, V-groove paneling 30.3%, and flooring 36.7%. The last column of Table 5 indicates the piece count and lineal footage loss for possible product upgrade by cutting to remove the principal grade limiting defect.

Millwork grade C and D is most frequently sold through the lumberyard or other retail outlets and home improvement centers. Many producers of custom millwork or small volume manufacturers often distribute product for sale to local

**Table 6. Beaded ceiling millwork cut to 29-in. pieces of C and better**

Appearance classification	Face coverage (in.)	Piece count	Lineal (ft)	Volume (bf)	Coverage area (ft <sup>2</sup> )
Nail free, sound tight knots	5-3/8	190	459	230	206
Residual nail holes with associated metallic stain	5-3/8	82	198	99	89
<b>Totals</b>		<b>272</b>	<b>657</b>	<b>329</b>	<b>295</b>

markets without strict grading according to written grade rules. Finish-ready millwork is often sold as firsts (limited to a few small sound knots) or as seconds (greater number and larger size sound and unsound knots allowed). Seconds lumber is sometimes labeled as rustic. Rustic millwork is in many ways equivalent to an E-grade quality of millwork.

Niche markets are an important sales outlet for the custom millwork producer. Often these small producers lack the capacity to carry the volumes of product necessary to supply retail distribution channels. A business developed to remanufacture hemlock lumber from deconstruction likely would sell product to this niche market, possibly as a principal outlet. One specialty-oriented product to satisfy a niche consumer market is wainscot as a decorative wall treatment. Popular for homes and offices, wainscot usually includes a pattern panel cut (often with a beaded decoration) and is installed from the floor to a 29- to 31-in. wall height and includes base and top rail moulding. Wainscot, like flooring, is an ideal product to produce from deconstructed lumber, as relatively short pieces of lumber can be utilized.

Much of the feedstock to be used for beadboard paneling had a large number of nail holes, which lowered the grade of the paneling produced (typically to the lowest E grade). Rather than produce long-length beadboard ceiling of lower grade, we cut out the nail holes and converted the 5-3/8-in. face coverage beaded paneling to the shorter 29-in.-length wainscot with a C or better grade quality. Table 6 summarizes this effort.

Beaded ceiling paneling included an initial 1,102 lineal footage (Table 2) of the processed millwork. Improvement in quality resulted in a total cutting loss of 445 lineal footage of below-grade material. This activity also served to identify any missed end-splits not removed during the first cut-to-length processing task. We did observe that many pieces of millwork developed end-splits after moulding. Much of this defect was believed to be related to moisture-related drying stress and could have been avoided if the lumber had been kept dry after deconstruction.

## Visual Demonstrations

The produced V-groove paneling and log siding were installed in a building to provide a visual presentation of the remanufactured eastern hemlock (Figs. 18, 19). Discussions with the owner of Quenhanna Millworks, who regularly produces log cabin siding from hemlock logs, indicated that

his customers prefer the log cabin siding over the V-groove paneling for interior walls. He indicated that many customers remodel studies, dens, family- or living rooms and will use the siding to accent fireplaces and country-style kitchens.

From an aesthetic standpoint, we observed that the millwork produced from the reclaimed lumber has a more intense coloration (slightly darker and richer) than the same millwork produced from freshly sawn hemlock logs. This patina may be due to oxidative changes in the wood extractives over time. This particular trait may benefit market sales to buyers with a special interest in a vintage or antique wood look (Figs. 18, 19).

## Conclusions and Recommendations

This study focused on the technical feasibility of producing a value-added wood product from reclaimed hemlock lumber. In a research study of this type, it is not realistic to quantify labor costs for the various tasks while trying to collect technical data. However, we do have a few recommendations that would help reduce the time and effort to prepare the lumber for remanufacture. First, we recommend that more trimming be done on the jobsite. Eliminating rotated ends and obviously unusable sections of lumber would save on transportation costs, labor to load and unload, and disposal. The authors probably paid too much for the raw materials used in this study given the poor condition of many of the pieces. Purchasing lumber for use in remanufacture requires a savvy buyer to minimize front-end costs. As much as possible, we recommend purchasing metal-free lumber, which would minimize the labor of pulling nails.

The authors believe that costs could be further reduced in a re-milling operation with a constant stream of material and of a volume large enough that some economy of scale could be achieved in material handling and machine throughput.

Finally, does this process have commercial viability? Though this study was focused on determining technical feasibility, not profitability; the authors believe that if the above recommendations are followed, it is possible to establish a viable business remanufacturing this material. However, paramount to success is the need to minimize the lumber purchase price, develop efficient metal removal processes, optimize a moulder throughout, and establish a network of niche-market customers.





**Figure 18—V-groove paneling of mixed grade qualities (left) and the higher C grade quality (right).**



**Figure 19—Log cabin siding on an interior wall section (7-in. width).**